THE
JOURNAL
OF THE SOCIETY OF
AUTOMOTIVE
ENGINEERS

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MAY 1921

The New Industrial Era—
A Buyer's Market

THE new era and market already exist. And in it, quality will dominate.

In all lines of industry—and notably in the automotive field—the buying public looks upon past performance as a criterion of future sincerity of purpose and dependability of product. Manufacturers content with the use of any material to "get by" will be out of step with this new industrial progress and buyer demand.

Satisfactory service in motor cars demands much of its bearings because bearings cannot escape wear. But Non-Gran bushings resist that wear from three to eight times longer than bushings of any other bronze before first accuracy of fit is destroyed.

Why? Because Non-Gran is tougher, less granular and more dense in physical structure. Its resultant greater resistance to frictional pull—which is wear—insures a longer period of satisfactory service.

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West Baden Meeting

AUTOMOTIVE engineering interest is directed this month to the State of Indiana and the Semi-Annual Meeting of the Society at West Baden, May 24 to 28. The reservations at this writing, five weeks in advance of the opening date, have passed the 400 mark and each mail increases the total. Fortunately, West Baden Springs Hotel has sufficient capacity to house a large convention comfortably and there are still many pleasant rooms available.

OUTLINE OF TECHNICAL SESSIONS

The programs of most of the technical sessions are completely arranged and the members will find them most interesting and instructive. The Research and the Fuel Sessions will undoubtedly rank first in point of general interest. As announced in the April issue of THE JOURNAL, Sir Dugald Clerk, the noted British scientist, had planned to visit America and attend the Summer Meeting. He has recently advised us by cable that illness in his family necessitates the cancellation of the trip at this time, but he has kindly forwarded the paper that he has written for the occasion and this will be discussed fully at the Research Session. There will be a paper on automotive engine and vehicle lubrication at this session by C. W. Stratford, whose previous contributions on the subject have created wide interest. Prof. W. E. Lay of the University of Michigan will present a paper on the automotive research facilities of the University, describing recent additions to the laboratory which will provide equipment for the study of the mechanical efficiency of the complete vehicle. The University of Michigan has recently established a Bureau of Research Investigation, and the faculty is anxious to cooperate with the industrial laboratories in attacking automotive research problems. There will undoubtedly be discussion of the research plan which the Society is contemplating and consideration given to the scope of this work.

The attainment of higher thermal efficiency in automotive engines and the employment of the less volatile oils as fuels will be treated by F. C. Ziesenheim of Carnegie Institute of Technology in his paper entitled Development of a High-Compression Oil Engine for Automotive Purposes. Dr. H. C. Dickinson and his colleagues, W. S. James and S. W. Sparrow, have prepared a most

interesting paper analyzing the fundamentals affecting passenger-car economy. George P. Dorris has developed a new manifold intended to convert the less volatile ends of the fuel into vapor before they enter the cylinder, thus eliminating dilution of the lubricating oil. His paper will describe this, and models also will be shown.

Other technical sessions will be devoted to aircraft, farm power, highway transport, and engineering relation to sales. V. E. Clark's paper in the Aeronautic Session will tell of the economic reasons for the present unsatisfactory status of commercial aviation and suggest possible remedies. S. H. Philbin will emphasize the necessity of adequate Federal legislation to secure the support of the substantial business man for air transportation. G. J. Mead will read a paper on Aviation Powerplant Development, criticizing the present practice of powerplant installation in aircraft and pointing the way to probable future development.

The Meetings Committee has decided to postpone the Tractor Session which was planned for the Summer Meeting. It was thought that it would be better to arrange a special Tractor Meeting for some future date, probably in connection with one of the regional tractor demonstrations. The Committee on Plowing Speeds preferred to defer the conduct of further tests to a date later than that of the West Baden Meeting.

Owing to a decision to give preference to the papers of a strictly engineering nature, of which an embarrassing number were submitted to the Committee in view of the time available at the sessions scheduled, the Engineering Sales Stimulus Session has been eliminated.

TRANSPORTATION ARRANGEMENTS

The reduced-fare plan which has been arranged with the railroads differs from the one in effect at the Annual Meeting last January. A reduced-fare certificate will be mailed to all of the members about May 1. This must be presented when transportation to West Baden is purchased and entitles the member to a reduction of 25 per cent. Round-trip tickets only may be purchased under this plan, no stop-overs are allowed, and the same route must be used in both the trip to West Baden and return. These certificates can be used only in two of passenger

association territories whose boundaries include most of the automotive centers. A map which will be mailed with the certificates will show clearly the area in which the-fare-and-a-half round-trip plan applies. Special Pullman and train arrangements are described in this issue of THE JOURNAL under the Activities of the S.A.E. Sections.

SPORTS

The Committee in charge of sports is busy completing arrangements for one of the most comprehensive programs ever conducted at an S.A.E. summer meeting. No matter what your specialty may be, the Committee will see that you have an opportunity to demonstrate your prowess. There will be everything from a tug-of-war to croquet. Tournaments are planned for golf, tennis and trapshooting, and there will be two baseball series. The prize-fund appeal was answered most acceptably, assuring the selection of suitable and useful rewards for many engineer athletes. The ladies will find card parties, clock-golf, croquet and tennis tournaments arranged for them, not to mention the dancing contest that has proved so popular at past meetings.

Remember the date, May 24 to 28; the place, West Baden, Indiana; the numerous professional and recreational attractions; then send in your application at once.

DESIGN OF TRANSMISSION AND AXLE GEARS

THE design of automobile transmission and axle gears has always been one of the most vexing problems in design owing to the fact that the tooth pressures which prove satisfactory for and permit adequate durability with different materials, heat-treatments, tooth faces, pitches and speeds are most difficult to determine. With the advent of the truck and tractor the same difficulties have been experienced. The general practice is to calculate the strength of gears by the Lewis formula and then revise the dimensions as indicated by past experience as to wear and general satisfactory performance.

It has been suggested recently that, inasmuch as heat-treatments and materials for gears have been generally standardized by the industry and as the satisfactory tooth pressures for automobile, truck and tractor transmission and axle gears are well established, standards should be determined giving the maximum tooth pressures permissible for various types and dimensions of teeth for different materials. It is however recognized that such standardization would have to be predicated on a large amount of research work to establish reliable data relative to various factors that determine the smooth operation and life of gear mechanisms.

It is fully appreciated that the development of general formulas taking into account all the many variables would be most difficult. Transmission and axle manufacturers have done considerable experimental work along this line, but to study the importance of particular factors it has been necessary to restrict the experimental work to a great extent. To undertake any general investigation that would apply to all kinds of transmissions and differentials and the methods employed in their manufacture would involve an immense amount of work on the part of those conducting such an investigation and the trade.

The present practice for testing gears is to cut all of them under absolutely the same conditions on the same machine, using the same kind of cutting compound and the identical cutter, as all of these factors tend to affect the serviceability of the finished gear. It was originally thought that the Brinell or scleroscope hardness would be a very good index of the wear, but it was found that while it is a factor it does not bear a direct relation to wear. Gears cut from two different analyses of steel, hardened to exactly the same degree with all other conditions as nearly alike as possible, showed a marked difference in wearing quality. This indicates that if it is desired to derive a formula for figuring gear teeth which includes as a factor the analysis of the steel, the problem would be extremely complicated. It is generally agreed that definite factors for certain conditions which would indicate the wear which might be expected from gear trains would be well worth the necessary cost and effort of obtaining them.

INDUSTRIAL EMPLOYMENT ANALYSIS

THE United States Employment Service of the Department of Labor has made an analysis of the industrial employment situation, the results of which are of unusual interest at this time. The reports state that between January, 1920, and January, 1921, employment in general was decreased by 35 per cent, and that in the automobile industry the percentage of unemployment was as high as 69 per cent. During the two months of February and March of this year, however, a decided recovery has taken place. The number of persons employed in the automobile industry on March 31 was 52 per cent higher than on Jan. 31, although for the same period there was a further reduction of 2.5 per cent in the number of persons employed in all industries. This shows that while last year the automobile industry was the first to feel the falling off in business, it has on the other hand already started to recover substantially. It would seem from these figures that this industry might be considered as a barometer indicating several months in advance the probable trend of business in general.

The United States Employment Service has obtained this information from over 1400 firms, each normally employing over 500 men, representing 14 industrial groups subdivided according to geographical location. It is planned to make this survey continuous, and figures will be given out by the Department of Labor monthly, showing the employment situation throughout the country. These bulletins should be of extreme interest to every manufacturer as indicating not only business conditions but also the trend of wages and the purchasing power of the different sections of the country. These monthly analyses are issued under the title of Industrial Employment Survey Bulletins by the United States Employment Service, Department of Labor, Washington.

HIGHWAY TRANSPORT

I FIRMLY believe that the development of road construction and the use of the motor truck is the next great industrial development to take place in this country, and if intelligently considered and wisely applied, it will open up sources of immeasurable national wealth and contribute to the welfare and comfort of our people to a degree that has rarely, if ever, been equaled by any one method.—John S. Cravens.

UNITED STATES FOREIGN TRADE

UNPRECEDENTED totals were attained in American foreign trade for the fiscal year ended June 30, 1920. The merchandise that passed through our ports, in both directions, was valued at $13,349,661,401, exceeding by more than $3,-000,000,000 the highest previous figure which was recorded in 1919. Imports of merchandise totaled $5,238,621,668, as compared with $3,095,720,068 in 1919 and $2,945,655,403 in 1918.

Nebraska Tractor Tests

By Oscar W. Sjogren[1]

COLUMBUS FARM POWER MEETING PAPER   *Illustrated with* CHARTS

BEFORE taking up the results of the Nebraska tractor tests, I believe it would be well to state briefly the provisions of the law, the kind of tests conducted and the equipment used, so that you may have somewhat of an idea of why and how the work is carried on.

Provisions of the Nebraska tractor law are as follows:

(1) A stock tractor of each model and type sold in the State shall be tested and passed upon by a board of three engineers under State University management

(2) Each company, dealer or individual who offers a tractor for sale in Nebraska shall have a permit issued by the State Railway Commission. The permit will be issued after a stock model of the tractor has been tested by the University and the performance of the tractor compared with the claims made for it by the manufacturer

(3) A service station with a full supply of replacement parts for any model of tractor sold in the State shall be maintained within the confines of the State and within reasonable shipping distance of customers

(4) Enforcement of the provision of the law is placed in the hands of the State Railway Commission

The official test includes a series of runs or tests as follows:

(1) Twelve-hour limbering-up run, beginning with one-third load and gradually increasing the load until the tractor pulls practically a full load for the last 3 of the 12 hr. The object of this test is to give an opportunity for the tractor to limber up under the supervision of a factory representative

(2) Brake-horsepower test at the rated load and speed for 2 hr. This gives an opportunity to observe the behavior of the tractor under its rated load and also gives a record of the fuel consumption

(3) Brake horsepower for 1 hr. at a load varying from the maximum to no load for 10-min. periods with the engine set as for the rated load test. This test continues for 1 hr. The object of this test is to show the fuel consumption under variable load and speed control of the governor

(4) Brake-horsepower test at maximum load for 1 hr. with the governor set to give full opening of the throttle-valve and the carbureter adjusted to give the maximum power at the rated speed

(5) Brake-horsepower test at one-half load for 1 hr. and the governor set as for rated load and carbureter adjusted for the most economical operation at this load

(6) Drawbar-horsepower test at the rated load for 10-hr. continuous run. This test is carried out on a half-mile cinder track, the load being the Nebraska dynamometer car which will be explained briefly later on

(7) Maximum drawbar-horsepower test. This test con-

sists of a series of short runs with an increase of the load for each run until the engine is overloaded or the drive wheels slip excessively. We are contemplating making a change in this maximum test for the coming season, namely to continue it through a period of 1 hr. with the maximum load which the tractor will pull for that time. The purpose of the maximum drawbar test as conducted during last season was to determine what load the tractor could pull for short distances

(8) Miscellaneous test. This includes an investigation of work on inclines, turning radius, effectiveness of brakes, or any other feature which may seem to require special observation

The tractors are under observation throughout the complete test as outlined above. The length of the official tests varies from a minimum of 28 to a maximum of 54 hr.

EQUIPMENT USED

To carry out the work properly it was found that a special building would be necessary, inasmuch as no building was available, upon the campus, suitable for the purpose. A hollow-tile building was constructed, having a width of 41 ft. and a length of 82 ft. with 14-ft. ceiling. The question of ventilation and providing of outside air was gone into and to provide as free movement of air as possible very large door openings were used and an abundance of windows provided. The outside walls of the testing shed contain approximately 2340 sq. ft. of wall space. Of this area 294 sq. ft. consists of windows and 232 sq. ft. of door space, making a total of 526 sq. ft. of window and door openings, or approximately 22 per cent of the wall space. Besides this, two ventilators, in which exhaust fans are installed, are placed in the ceiling.

All brake tests were made on a Sprague electric dynamometer of 150-hp. capacity. This dynamometer is driven through an extension shaft mounted on ball bearings carrying a pulley 10 in. in diameter with a 12-in. face. No allowance is made for belt loss. Various types and sizes of belt are available to provide the builder with what he deems to be most suitable for his tractor, or he may provide his own belt if he so desires. Besides the dynamometer and the belts, various other equipment, such as scales, scale tanks, weighing-stands, speedcounters, tachometers, fuel-testing equipment, etc., is provided.

The drawbar tests were made on a half-mile cinder track, the surface of which is slightly rolling, no grade, however, being greater than $3\frac{1}{2}$ per cent. To provide a load on the tractor which could be fairly well controlled at all times a special dynamometer car or loading machine was constructed which in the main consisted of a tractor chassis, carrying an electric generator mounted in place of the engine. This generator is driven from the drivewheels as the car is pulled by the tractor. This machine furnishes a maximum drawbar pull of about 5000 lb.

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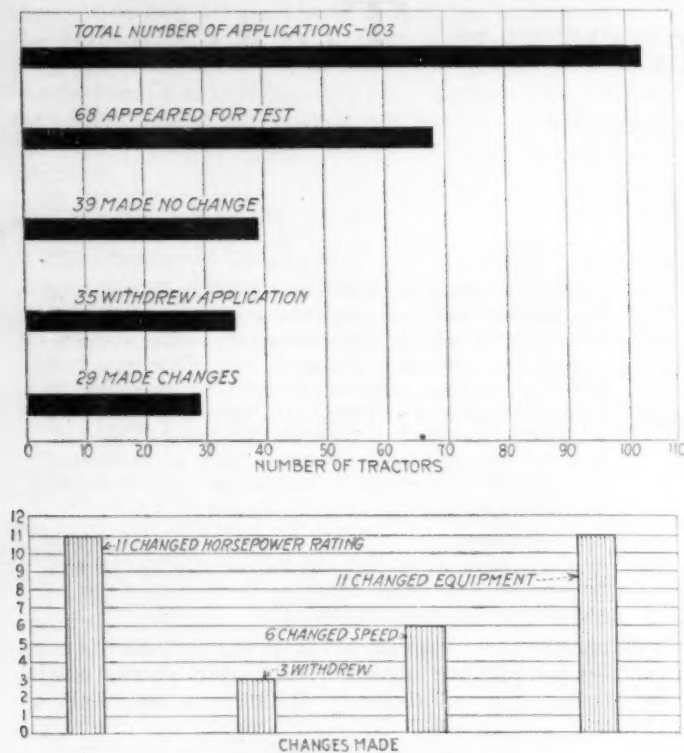
FIG. 1.—SUMMARY OF TRACTOR TESTS

When it is necessary to provide a greater drawbar pull than this, various loads are attached behind the car until the desired pull is obtained. The 10-hr. continuous run demanded by the law makes this part of the test the most difficult of all the runs.

A word may be said here of the operators in order that it may be understood that the various machines were operated by the same set of operators while records were taken. On the preliminary run a representative of the tractor firm operated the machine to be sure that it was
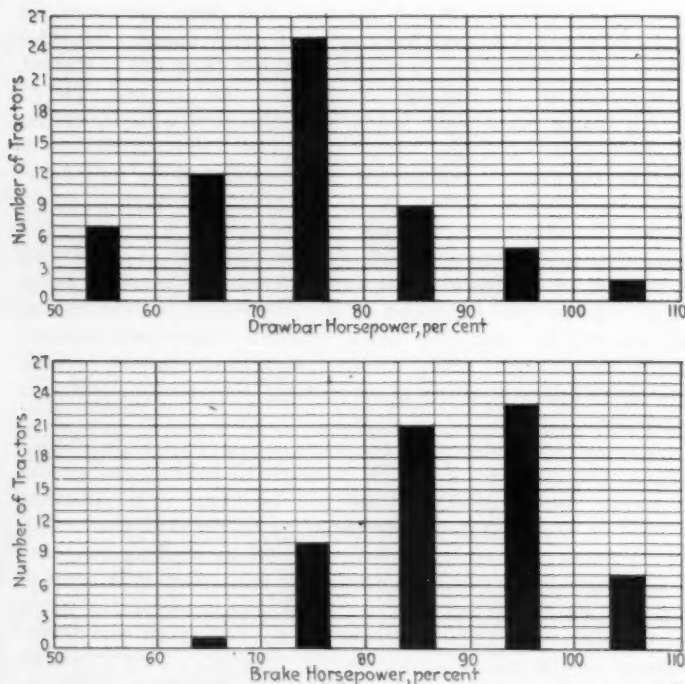

FIG. 2—RATED DRAWBAR AND BRAKE HORSEPOWER IN PERCENTAGES OF THE MAXIMUM DELIVERED IN THE TESTS

working properly. On all other tests the University furnished its own operators, as this was thought to be the most satisfactory to all concerned.

RESULTS OF THE TESTS

Applications covering 103 different tractors were received for the season. Of these 68 appeared for test, 35 withdrew their application without appearing for test. The reasons for withdrawal were various, such as models becoming obsolete, curtailing of production, restriction of territory, etc. Of the 68 which appeared for test 39 went through without making any changes, while 29 made changes as indicated in Fig. 1. Of the 11 which changed equipment, 2 also changed their rating. One of the three which withdrew later made reapplication, appeared and went through the test.

In the figures covering the belt horsepower and the drawbar horsepower the maximum delivered at the brake or drawbar has been used as a basis of 100 per cent and the rating is therefore given in percentages of maximum in Fig. 2. Three tractors were not rated and two have discontinued the belt rating. It is seen that only 11 machines come within the former S. A. E. Standard belt rating, while 51 machines carry a rating higher than was permitted by that standard.
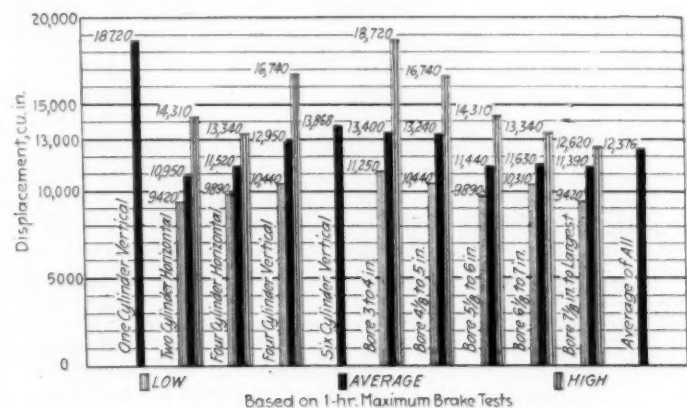
FIG. 3.—PISTON DISPLACEMENT PER HORSEPOWER-HOUR IN CUBIC INCHES FOR VARIOUS CLASSIFICATIONS OF TRACTORS

Studying the results of the drawbar tests, we find that this condition is changed, a more liberal rating being given on the drawbar work. It must be kept in mind, however, that this maximum drawbar horsepower from which these data are drawn is obtained during a very short interval of time. It serves, nevertheless, to indicate that the drawbar rating is more liberal than the belt rating. It is seen that 44 tractors fall within the former S. A. E. Standard drawbar rating, 7 being rated at approximately half of what they can do and 16 carrying a rating higher than the said standard indicated, 2 of these being rated at more than they can actually develop.

A chart compiled showing the cubic inch displacement per horsepower of various classifications of tractors and reproduced in Fig. 3 gives some interesting comparisons. These cubic inch displacement figures are all taken from the 1-hr. maximum belt test. Of the 65 tractors tested the lowest piston displacement is 9420 cu. in., which is for a two-cylinder horizontal machine. That this type, however, does not have a lower piston displacement than the other types is shown by the chart. The highest piston displacement is 18,720, which is for a one-cylinder vertical machine. This figure, being from only one machine, should not be taken as conclusive that all one-cylinder tractors have a high displacement. It is noted

that there is almost a 100 per cent variation in the piston displacement shown by the lowest and the highest, and that there is a great variation in each class as to the two classifications shown.

In the classification of tractors as to belt speed in feet per minute the results obtained are shown in Fig. 4. The standard belt speeds of 1500, 2600, 3000 and 3500 ft. per min., as adopted by the Society, and the additional speed of 3250 ft. per min., adopted by the National Implement and Vehicle Association, are shown at the base of this chart and are indicated by the heavy vertical lines. It will be interesting to compare the belt speeds a year or two after these standards have been in operation and note whether any effort is made to conform to the standards.

FUEL CONSUMPTION

The fuel consumption has been studied from the three different angles of volumetric displacement, engine speed
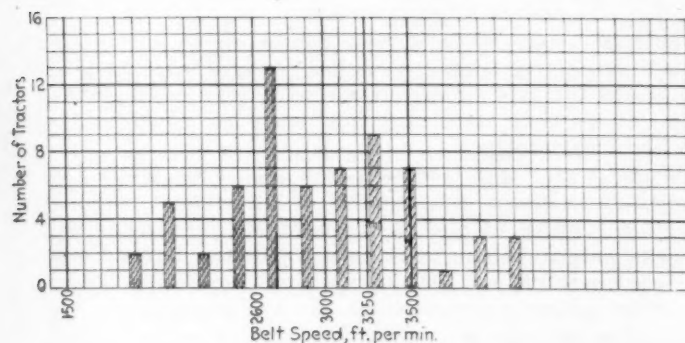
FIG. 4—CLASSIFICATION OF TRACTORS ACCORDING TO BELT SPEED

and the diameter of the cylinders. The curves reproduced in Figs. 5 and 6 do not happen to be smooth, but they indicate in a general way the relation of fuel consumption to those three factors. The lowest fuel consumption secured during the season on belt work was 0.63 lb. per hp-hr. with an air temperature of 58 deg. fahr., and the

TABLE 1—CLASSIFICATION OF TRACTORS ON BASIS OF PISTON DISPLACEMENT

Piston Displacement, cu. in. per min. per hp.	Number of Machines
9,000 to 10,000	3
10,000 to 11,000	7
11,000 to 12,000	10
12,000 to 13,000	19
13,000 to 14,000	12
14,000 to 15,000	7
15,000 to 16,000	4
Over 16,000	3

highest was 1.27 lb. per hp-hr. with an air temperature of 100 deg. fahr. On the drawbar work the lowest was 0.98 lb. per hp-hr. with an air temperature of 76 deg. fahr., and the highest was 3.02 lb. per hp-hr. with an air temperature of 89 deg. fahr. Table 1 gives the number of tractors in each class according to piston displacement.

TABLE 2—CLASSIFICATION OF TRACTORS ACCORDING TO ENGINE SPEED

Speed, r.p.m.	Number of Machines
375 to 500	3
500 to 700	11
700 to 900	16
900 to 1,000	14
1,000 to 1,200	15
1,200 to 1,500	5
Above 1,500	1
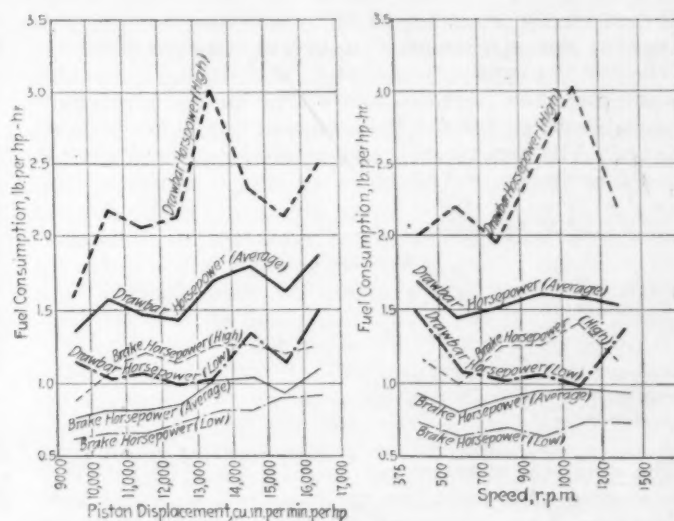
FIG. 5—FUEL CONSUMPTION IN POUNDS PER HORSEPOWER-HOUR BASED ON THE PISTON DISPLACEMENT IN CUBIC INCHES PER MINUTE PER HORSEPOWER AT THE LEFT AND AT THE RIGHT ON ENGINE SPEED

Based on engine speed, it will be seen that the fuel consumption tends to increase with the engine speed, although the difference is not great. The average shows a minimum of 0.8 lb. per hp. at about 600 r.p.m., it being greater at both higher and lower speeds. The number of tractors in each class is given in Table 2.
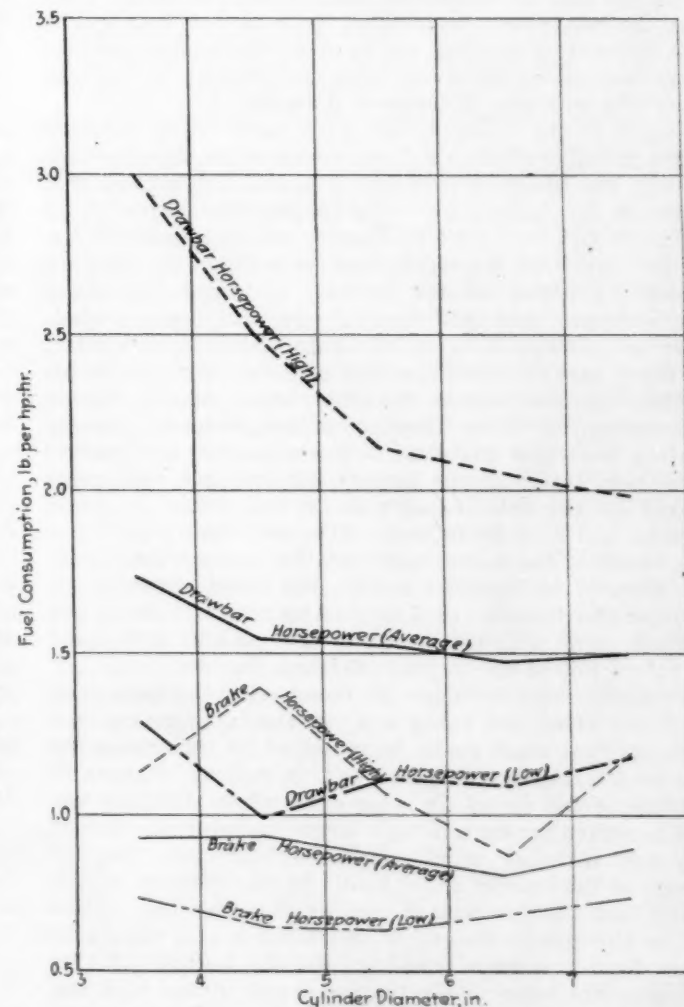
FIG. 6—FUEL CONSUMPTION BASED ON THE DIAMETER OF THE CYLINDERS

Based on the diameter of the cylinders, the fuel consumption shows a tendency to decrease as the diameter of the piston increases until the 7-in. diameter is reached. As the diameter increases above that figure there seems to be a tendency for the fuel consumption curve to start upward. The number of tractors for this classification is divided as shown in Table 3.

TABLE 3—TRACTORS CLASSIFIED ACCORDING TO CYLINDER DIAMETERS

Cylinder Diameter, in.	Number of Machines
3 to 4	13
4⅛ to 5	28
5¼ to 6	9
6⅛ to 7	8
Above 7	7

The water consumption per hour for the different tractors showed wide variation, running from no water used during the 2-hr. rated test at an air temperature of 84 deg. fahr. to 50 gal. for the same test when the air temperature rose to 88.5 deg. fahr. On the drawbar test the amount of water required varied from nothing at an air temperature of 77 deg. fahr. to 17.8 gal. per hr. with an air temperature of 87 deg. fahr.

WEAK SPOTS

The weaknesses of the tractor are not discussed here with the idea of criticizing the builder, for we all know that he has enough troubles of his own, but rather with the thought of singling out some of the weaknesses that have been shown up in our work in Nebraska, in the hope that this will help to improve the product.

Some of the changes that were made while the tests were in progress were a direct result of placing the tractors in the hands of operators who had not worked with them at the factory and as a consequence were not familiar with every little peculiarity of the particular machine. Some of the weaker points which may have escaped the notice of the designer or which have been ignored have thus been brought out. No changes whatever were made as a result of incompetent operators; in every case the machines had a fair trial at the hands of the operators under the observation of the tractor representative. It has been noted throughout our tractor testing work that doubtless in many cases as the tractors have been tested at the factory defects have been overlooked by the tractor engineer in his desire to obtain results, and as a consequence when the tractor gets into the hands of the actual user trouble develops altogether too soon. I believe that much good would result if the tests at the factory could be run by men who have had nothing to do with the design of the machine and would therefore not be apt to pet it through the test.

Probably more trouble was found with fan-belts than with any other one thing and yet this appears to be a difficulty that could easily be remedied by increasing the size or altering the shape of belt or making changes in the type of fan drive. In other cases where difficulty was had to secure proper cooling a larger radiator or a larger fan was installed which improved materially the behavior of the tractor under load. In one instance it was found that the fan was of smaller diameter than called for by the specifications. It developed that a supply of these fans had been furnished to the builder of this tractor. For some reason they were not turned back but were used and as a result trouble developed when the tractor was put under a heavy load. Other cooling difficulties indicated that the water space, especially in the cylinder-heads, might be too small. This was indicated by the heads becoming very hot, giving considerable spark-plug trouble, and yet the cooling water did not reach a temperature of 200 deg. fahr.

That the problem of the amount and degree of heated air to be taken into the engine is not yet solved is indicated by the many cases where difficulty was had in maintaining the power of the engine as it became warmed-up. During the warming-up period the engine would perform well, holding its required load, but as the temperature of the cooling fluid became constant and the engine was working hard, the power output began to drop. Trials were then made by installing by-passes and shrouds which permitted the taking in of cold air in various amounts. It was found that if as the engine warmed up the amount of heated air admitted could be cut down and the amount of cold air increased, the power output could be maintained. This led some of the firms to install automatic air-heating regulating devices on their tractors with good success.

In some cases when it was impossible to obtain the rated horsepower from the engine, changes were made in the make and type of carbureter with very good results. This shows that close attention must be given to the choice of carbureter.

Where water is mixed with the fuel some method is necessary to give a close control of the amount supplied for this purpose. This was brought out very strikingly in some cases. In one instance in particular I recall that the engine would not develop within 2 hp. of its rating. By substituting a needle-valve for a globe-valve in the water line and adding a sight feed, the amount of water added could be regulated very closely, enabling the engine to develop power slightly above its rating.

Much remains to be learned about the design and use of air-cleaners. With the dry air-cleaners the most frequent difficulty seemed to be an effort to use a size entirely too small for the tractor, resulting in power below the rating. By disconnecting the cleaner in such instances the engine could develop its rating. The question of size is important also with the moist air-cleaners, as is the matter of replenishing the water supply while the engine is in operation. This latter is especially important when working the tractor on the belt. The farmer dislikes very much to have to stop the machine at frequent intervals to replenish the water in the cleaner and after some experience of this kind will likely disconnect it, thus losing the protection that it is supposed to provide.

It is probably superfluous to mention the inadvisability of the use of kerosene in a gasoline engine and yet it is permitted in some tractors with anything but satisfactory results. I believe that the builder of the gasoline tractor would save himself a lot of grief if he would discourage the use of kerosene in such a tractor.

The purpose of a governor on an engine is to prevent any appreciable variation in the engine speed. In many cases "governor" was a misnomer, while in others splendid results were obtained. The closest regulation given by any governor had a variation of 0.4 per cent above and 0.9 per cent below the rated speed. In this case the governor was set to give the rated speed of the engine while idling. The greatest variation was 55 per cent above the rated speed. Of the 65 tractors tested, 30 had governors which gave a speed regulation within 10 per cent of the rated speed, and 35 went above this figure. Of the latter, 13 varied more than 20 per cent and two more than 50 per cent above rated speed. In no case did the variation below rated speed exceed 7 per cent.

A study of the log sheets giving readings every 10 min. seems to indicate a close relation between the speed control and the fuel consumption. Where there is a fluctuation in the engine speed on the 2-hr. rated load test there is a corresponding fluctuation in the fuel consumption at each 10-min. interval and likewise where the speed is practically constant throughout this test the fuel consumption readings at the 10-min. intervals are more nearly constant. It seems, therefore, that in the interest of fuel economy a close regulating governor is desirable.

Belt pulleys of the types which can be attached or taken off readily gave considerable trouble. This is no doubt due to their having a short shaft and usually only one bearing. The pressure upon such an arrangement is large and subjects it to severe usage.

There was lack of proper clearance in some cases between the face of the belt pulley and the drive-wheels. Under wet-soil conditions this may give considerable difficulty by the filling on the drive-wheel rubbing on the belt pulley, thus causing a stalling of the engine. A desirable arrangement of the belt pulley and starting provision which is lacking on some tractors is the ability to crank the engine and start it while in the belt. This is very desirable from the standpoint of a "one-man machine."

The weight distribution or method of attaching the load or both are often such as to make the weight on the front wheels too little and as a result these wheels do not bear down upon the soil heavily enough to cause the tractor to turn readily, especially when pulling a heavy load. The guiding mechanism is in constant use while the tractor is operated on drawbar work. In view of this fact, it should be designed so as to be operated more easily on a number of machines.

More attention should be given to providing means for the operator's comfort and convenience in the matters of seat design and arrangement and accessibility to the various parts of the tractor for inspection, adjustment and repair. Often the seat is placed directly in the path of the fan blast, without any effort being made to deflect this blast of hot air and, consequently, the operator must endure this heat in addition to the hot weather during the working seasons. In other instances the operator is compelled to be seated astraddle of a transmission case which virtually becomes a boiling volcano. The matter of replenishing the supply of water in the cooling system and in the air-cleaner, as well as lubricating the tractor while it is in operation, seems to have been overlooked in a number of instances.

That the condition of the valves is looked upon by the factory as a minor matter is indicated by the fact that in 16 different tractors the valves were ground after the test was started, the power output being thereby materially increased. A number of these cases gave evidence of the work of fitting and grinding the valves having been improperly done at the factory. It should be remembered that the farmer and often the service man do not have at their disposal the equipment for this work

that is available at the factory, and this should be given proper attention there. The farmer expects the newly purchased tractor to serve without the necessity of immediate attention to such matters and rightly so.

That the matter of proper spark-plugs has not been satisfactorily solved is shown by the records which disclose that 42 spark-plugs had to be replaced during the testing season. This in itself is not indicative of any serious difficulty in this respect, but when it is noted that the trouble was due to the points burning or breaking off and the blowing out of plugs, it indicates that some builders have not found a plug that works satisfactorily in their machines.

The changes made necessary in the large percentage of the tractors submitted for test indicate that the power ratings are made on too narrow a margin. Other tractors went through the tests with a very liberal margin above their rating. This wide difference should be eliminated and ratings made on a uniform basis. The sooner this is done the better it will be for the industry, as it will eliminate a large amount of suspicion on the part of the purchaser. If he can feel certain that a 30-60 tractor of one make is equal in power to a similarly rated tractor of any other make, he will have more confidence than he has now. The results of the test allow a comparison to be made of tractors using the same make

TABLE 4—DIFFERENCES IN THE RATING OF THREE TRACTORS USING THE SAME ENGINE

Tractor	Rating, hp.	Speed, r.p.m.	Maximum Belt Power, hp.	Drawbar Pull, lb.	Speed, m.p.h.	Power at Drawbar, hp.
A	6 to 12	1,000	12.37	1,142	2.06	6.27
B	5 to 10	1,000	11.34	1,189	1.79	5.66
C	6 to 10	1,200	13.31	1,310	2.84	9.92

and model of engine. For instance, three different tractors use the same $3\frac{1}{8}$ x $4\frac{1}{2}$-in. engine and are rated differently as is brought out in Table 4.

Here is a variation in rating of A and B of more than 8 per cent and yet they have the same engine operating at the same speed. Tractor C is rated lower on the belt than A and yet the engine is operated at a greater speed. It is plainly evident that here are differences in rating for which there are no consistent reasons. The same condition holds true though not so markedly with larger tractors using an engine of the same make and size.

To sum up what has been said, the difficulties can be classified into five divisions. These are (a) engine troubles, which are dependent upon the design of the engine and the correlation of different parts; (b) accessory troubles, which depend upon the choice of the proper accessories and their adaptation to the engine; (c) proper correlation of the parts and the design of the chassis to fit the engine and permit the most efficient use of it; (d) testing of finished tractors by others than designing engineers to bring out minor difficulties; and (e) rating the tractors to give a liberal allowance for overload.

The Consequential Advantages of Weight Reduction

By L. H. Pomeroy[1]

IT is generally admitted by engineers that any steps toward the reduction of chassis and body weights are desirable in the interests of economy but it is not unusual to find that weight reduction is looked upon as incompatible with reliability and road holding properties. The weight of an automobile chassis is determined on the one hand by the engine power and the required strength of the transmission to transmit the torque developed and on the other by the strength of the axles, springs and frame in their relation to the shocks imposed by road inequalities and driving strains. In brief, if automobiles had to be designed to run on railroad tracks up mountains the engine and transmission would be the chief determinant of the total weight as the shocks imposed on the axles and the frame would be very small. Conversely if automobiles had to be designed to run from the top of a mountain to the bottom over very rough roads the weight would be principally determined by the requirements of the frame, springs and axles.

Apropos of this the rear-axle is a member which supports the weight of the car and also transmits the engine torque to the wheels, while the front axle is virtually a load-carrying member solely, its stresses being independent of the engine torque for any given speed and car weight. It is a matter of simple calculation to determine the remarkably small average horsepower developed in the propulsion of a full-sized passenger car. At 30 m.p.h. this amounts to about 8 hp. and in the majority of cases is not more than 25 per cent of the horsepower available. Taking a typical case of an engine say of 240-cu. in. cylinder capacity, a gear ratio of 4.5 to 1 and 32-in. wheels, the engine speed corresponding to 30 m.p.h. is approximately 1350 r.p.m. while about 36 b.hp. is available at that speed. Approximately 4 hp. is absorbed in internal friction so that the 8 hp. required to propel the car is attended with a loss of 4 hp. and the mechanical efficiency of the engine under these conditions is only about 66 per cent. This simple calculation indicates the necessity not only of obtaining high mechanical efficiency in automobile engines, but of reducing the absolute friction loss as it is such a large proportion of the average power exerted. It is obvious that the larger the engine the greater the absolute loss and one of the consequential advantages of reducing the size of the engine, in addition to the reduction in weight, is that its absolute friction loss is proportionally reduced, apart altogether from mechanical efficiency as such.

Aluminum for Various Parts

The use of aluminum for pistons is a well-known method of reducing inertia stresses and bearing pressures and in conjunction with the use of forged aluminum connecting-rods reveals the possibilities of wholesale weight reduction. The factor which probably determines the maximum horsepower which can be continuously developed is the loading on the big end of the connecting-rod. This is very largely a function of the mass of the piston and connecting-rod at high speeds so that if this total mass can be halved as is easily possible by the use of aluminum, the safe engine speed can be increased over 40 per cent, or alternatively the same engine speed can be maintained with a 40 per cent reduction in the amount of bearing surface. I am fully aware of the difficulties in utilizing this idea to its fullest extent, but it is seriously suggested that the possibilities of weight saving by shortening bearing lengths is full of the greatest potentialities.

The example of the piston and connecting-rod, in which reliability is distinctly a function of their lightness and not of their weight, applies in general to all parts of an automobile in which the stresses are determined by road shocks and speed. It is of the utmost importance, therefore, in the interest of reliability to reduce the weight of all parts which are so stressed. This is particularly emphasized in axle design where the effect of road shocks is strictly proportional to the axle weight. In addition axle weight reduction brings with it enhanced road holding properties as the relation of sprung to unsprung weight is reduced. The argument in support of this is precisely analogous to that demonstrating the necessity of light valve gear on a high-speed engine. The extended use of aluminum makes axle weight reduction possible and I would call attention to an axle I have recently designed in which the complete weight of the axle together with brake drums, aluminum disc wheels and tires is about 290 lb. This axle has been driven some 11,000 miles as fast as possible over very bad roads and has demonstrated conclusively its reliability and furthermore the fact that good road holding is just as practicable in a light car as in a heavy one.

Engine size and chassis weight pursue each other in a vicious circle. Because the engine is large it is necessary that the running gear and transmission shall be heavy, and because the latter is heavy it follows that the engine size must be increased to get any desired performance. By tackling the problem of reduction literally from the engine to the wheels, the amount of weight which can be saved without sacrificing reliability is surprising. The result is that with a car of the same general type a very much better performance is obtained. If improved performance is not required it is then possible to redesign and maintain the previous performance with a still greater reduction in the weight. One needs experience with the full-size light car to appreciate its economy, reliability, power of acceleration, speed and handiness. The trend of design in general and recent research in particular are along the lines of weight reduction without any sacrifice of essentials.

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Aluminum Pistons

By Frank Jardine[1] and Ferdinand Jehle[1]

Buffalo Section Paper   *Illustrated with* Drawings and Chart

IT is not the object of this paper to direct attention to the fact that aluminum pistons, due to their lightness, will reduce the inertia forces, thereby decreasing the engine vibration to a minimum and the bearing pressures to a reasonable amount; nor shall we point out that aluminum has a higher thermal conductivity and therefore reduces carbon deposits both above and below the piston head and permits higher compression pressures. These are advantages of aluminum pistons with which all engineers are familiar. We shall only try to point out the developments of aluminum pistons during the last year or so and to make suggestions for their design. This is, possibly, the age of piston invention and it may not be out of place to quote from Professor Diederich's translation of Güldner's Design and Construction of Internal-Combustion Engines, "Less invention more rational design." The internal-combustion engine has possibly both benefited and suffered more at the hands of inventors than any other mechanism, and the piston has received a considerable amount of the energy expended in these directions.

Whenever possible it is well to base a design on something that is known to have worked well before. It is not our intention to suggest that the engineering fraternity attach the same value to precedent as the legal profession, but it is well to follow closely along the design of something which we know has worked well. The aviation engine owes its success, in a large measure, to the aluminum piston. It would therefore be wise in designing an aluminum piston for automobile engines to follow somewhat along the general lines of aviation engine practice, taking into consideration the difference in the characteristics of the two engines. It is interesting to follow through the history of aluminum piston design. The first ones were copies of cast-iron pistons which may not nave been based on any particular theory. To gain the maximum advantage from lightness, aluminum pistons were at first made very, very thin, and then many ribs were added in the head to make them strong enough. About this time the Liberty engine piston was designed which eliminated ribs and utilized much heavier sections than had heretofore ever been used in any piston.

The Duties of a Piston

Before discussing the design further let us consider briefly the duties which the piston is called upon to perform. It plays one of the most important parts in transferring a certain percentage of the heat energy in the fuel into mechanical energy and it must also assist to a certain extent in providing a path for some of the waste heat. In the exercise of its first function it is necessary that it reciprocate and to do this with the least amount of disturbance it must be light. Furthermore the gas-engine piston is called upon to do the work which in the steam engine is assigned to three separate parts. It must

act as a gas tight plunger and as the piston rod, and it must also work as the crosshead.

In performing the function of plunger it must first of all be gas tight, that is not porous, and must also be of a material which will furnish a good seat for the rings. To perform the duties of a piston rod and a crosshead satisfactorily, it must fit the cylinder with a minimum amount of clearance so that there is very little play when the engine is cold, but with enough clearance so as not to be tight when the engine is hot. In the performance of its second duty, that of providing a path for heat, it is necessary for the piston to be made of a material which is a good thermal conductor. We know that heat enters the piston-head and that a large percentage of this must in time find its way into the water-jacket or cooling fins.

The most important function which the piston performs is that of converting heat into mechanical energy. Providing a path for some of the waste heat is a secondary duty or what we might term "a necessary evil." It is therefore of the utmost importance that the performance of this secondary duty interferes little or none with the performance of the first. Unfortunately up to the present time there has been interference. The heat passing through the piston may cause many undesirable effects such as self-ignition of the charge and excessive expansion of the skirt which necessitates a large clearance when the piston is cold. The first trouble, self-ignition due to a hot piston-head, is eliminated almost entirely by substituting aluminum for cast iron as the piston material. The second, that of clearance, is aggravated by substituting aluminum for cast iron, due to the greater expansion of aluminum.

It has long been recognized that pistons, whether they be made of cast iron or aluminum, must be kept as cool as possible. There has been no agreement among engineers, however, as to how this could best be accomplished. It was thought that if the inside of the piston, particularly the head, were provided with a great number of ribs, much of the heat would be radiated into the inside of the engine and to some degree at least the piston would be cooled by the oil splash. It does not seem reasonable to expect that any great amount of heat can be carried off in this manner. Prof. F. C. Lea, in a paper entitled Aluminum Alloys for Aeroplane Engines which was read before the Royal Aeronautical Society, states:

It is generally claimed that ribs assist in the cooling of the piston by transmitting heat to the air in the crankcase. The heat-balance sheet of an engine, however, shows that the total amount of heat carried away to the crankcase is comparatively small, and therefore, if the ribs are effective from the point of view of conducting heat from the crown to the skirt they are not effective in conveying heat from the crown to the air in the crankcase. Ribs may be required to strengthen the crown of the piston, especially in those of a greater diameter than 4 in., but it is very doubtful whether a

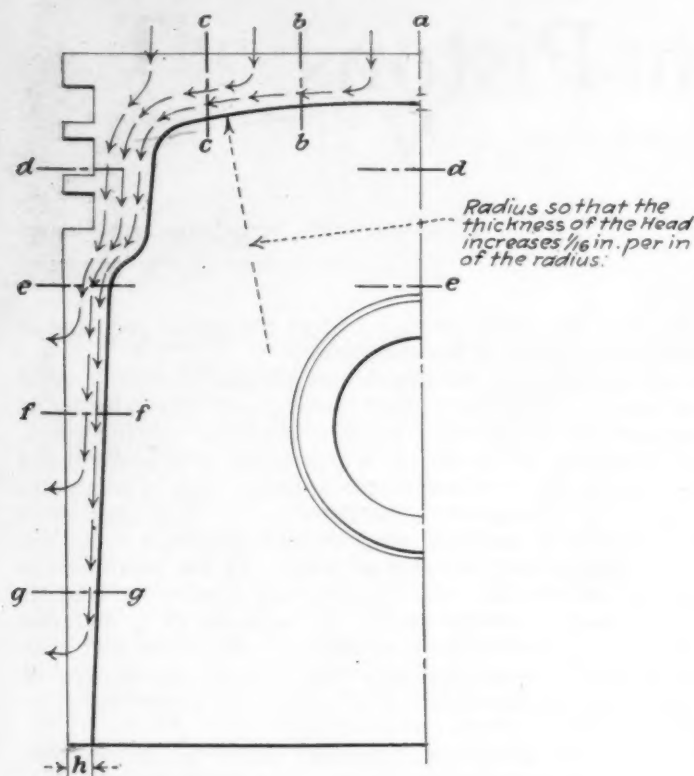[1] M.S.A.E.—Engineer, Aluminum Manufactures, Inc., Cleveland.

FIG. 1—DIAGRAMMATIC SKETCH OF A PISTON IN WHICH A GOOD PATH IS PROVIDED FOR THE HEAT TO FLOW FROM THE HEAD OF THE PISTON TO THE WATER-JACKET

large number of ribs such as are used in the Hispano piston, are of any value; one must, however, have an open mind upon this question; ribs certainly add to the difficulty of casting. The original sand cast pistons of the Sunbeam Arab engine had six ribs; by making four ribs instead of six, it was found possible to cast these pistons easily in the die, and running tests showed that the four-rib piston had no disadvantages as compared with the six-rib.

Tests which we have made on ribbed pistons and pistons without ribs on a Hall-Scott engine seem to confirm the same results. In these tests a careful record of the temperature of the oil and one of the main bearings was kept. Needless to say the quantity of oil in the crankcase was always kept constant. No difference in the temperature of either the oil or the bearing was detected, which could be attributed to the piston design; although a difference in the temperature of the bearing and the oil could be brought about by a change in the atmospheric temperature.

DESIGNS OF PISTONS

Col. E. J. Hall made the first piston design which came to our attention that had for its object the direction of the heat flow and provision of a good path from the head of the piston to the water-jacket. Fig. 1 is a diagrammatic sketch showing his general theory. The center of the head a must be thick enough to insure against the piston getting too hot at this point. Experiments which Colonel Hall made showed that this thickness should be 7 per cent. of the piston diameter. It is evident that the piston-head thickness must increase from the center to the wall in order to keep the temperature gradient at the minimum. A certain amount of heat enters between a and b, which amount must be conducted through the area b-b. Let us assume for the sake of argument that none of this heat is lost by radiation, then the section c-c must

conduct all of the heat which the section b-b transmitted, plus the heat which entered the piston-head from the area included between b and c. Each section farther removed from the center of the head of the piston must increase somewhat from the previous section. The scheme then was to provide sufficient metal behind the rings so that the great majority of the heat would be conducted through this path into the skirt of the piston and thence to the cylinder rather than through the rings to the cylinder wall. His experiments showed that the annular area of the section behind the rings d-d should be equal to one-quarter of the total head area. The section e-e which is below the rings should have the same area. In the skirt we meet the opposite condition from that in the head for each consecutive section must conduct less heat. Since some heat is transferred into the water-jacket from e-f the section f-f should have less area than the section e-e. By the same reasoning the section g-g need not have as great an area as the section f-f. When we get to the end of the piston at h all of the heat has been lost to the jacket, and therefore, h need have no area and consequently no thickness. Naturally it cannot be made without thickness for mechanical reasons such as strength in operation and for handling in the shop and foundry. The best thing we can do is to make h as thin as practicable. A piston of this general design was used in the Liberty engine and, as is well known, operated in a satisfactory manner. At this point it may be well to quote again from Professor Lea's paper,

> For pistons up to a 4-in. diameter a ribless piston with a domelike crown thickened toward the skirt and with a good fillet where the crown and skirt join is all that is required, and even for larger diameters it seems more than probable that such a construction would prove satisfactory. Experiments at the Royal Aircraft Factory have shown that such a piston runs cooler than one of the same weight with ribs.

Various attempts have been made to apply Colonel Hall's aviation piston to automobile engines with the result that while it worked very well from the thermal standpoint it was too heavy. It must be borne in mind that Colonel Hall's work was all done with pistons of about the same size, 15 in. or over, and with aviation engines. Aviation engines produce much more power per cubic inch of displacement and consequently more per square inch of piston-head area than automobile engines. The amount of heat entering the piston-head of an engine is not a function of its diameter but of the square of its diameter. The latter consideration makes it at once apparent that any formula for the head thickness of pistons varying over a great range of sizes cannot be based upon the diameter but must be based on the diameter squared. The total heat developed in the engine must next be taken into consideration; that is, we must take due account of the fact that the automobile engine produces less power per cubic inch of displacement and square inch of piston-head area than the aviation engine.

We shall now try to write a new formula taking these things into consideration. Starting with the Liberty engine operating at 1600 r.p.m. and developing 400 hp. we find that the horsepower per square inch of piston-head area is $400/(19.63 \times 12)$ or 1.7. Letting the head thickness vary with the area of the piston-head and the horsepower developed per square inch of piston-head area, we can write the following formula:

$$T = C_t D^2 H$$

where

T = Head thickness in inches
D = Piston diameter in inches
H = Horsepower per square inch piston-head area
C_t = A constant

In the Liberty piston $T = 0.375$ and $D = 5.0$.
Substituting these values in the formula

$$C_t = T/D^2H$$

we get

$$C_t = 0.0088$$

The wall area will also be a function of the heat entering the piston head. We may express this as follows:

$$A_w = C_w D^2 H$$

where

A_w = Wall area in square inches
D = Piston diameter in inches
H = Horsepower per square inch of piston-head area
C_w = A constant

Substituting the values for the Liberty piston of $A_w = 4.91$, $D = 5.00$ and $H = 1.70$ in the formula

$$C_w = A_w/D^2H$$

we get

$$C_w = 0.115$$

In using these formulas the maximum horsepower output of the engine should be used to determine H. It must
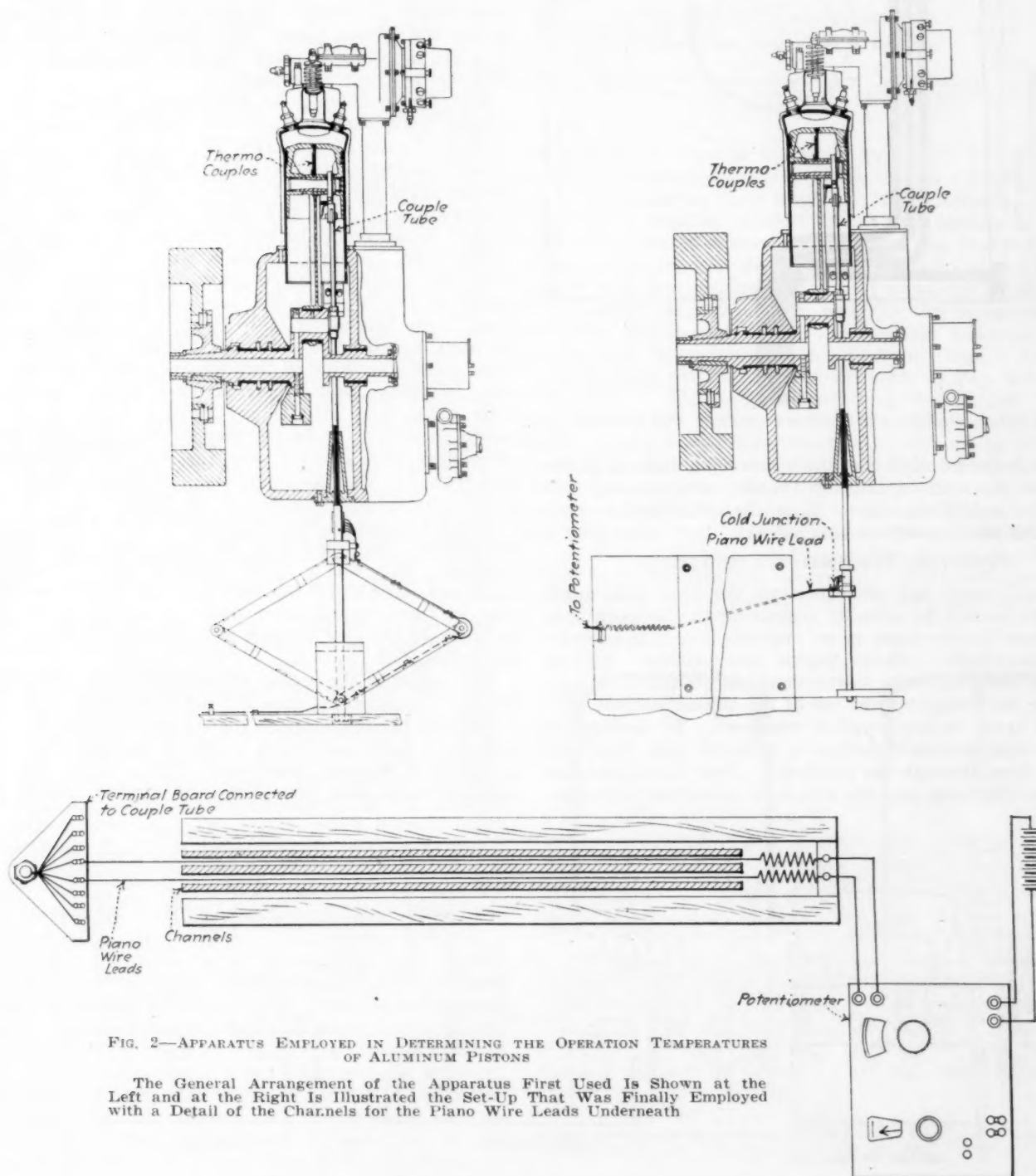

FIG. 2—APPARATUS EMPLOYED IN DETERMINING THE OPERATION TEMPERATURES
OF ALUMINUM PISTONS

The General Arrangement of the Apparatus First Used Is Shown at the
Left and at the Right Is Illustrated the Set-Up That Was Finally Employed
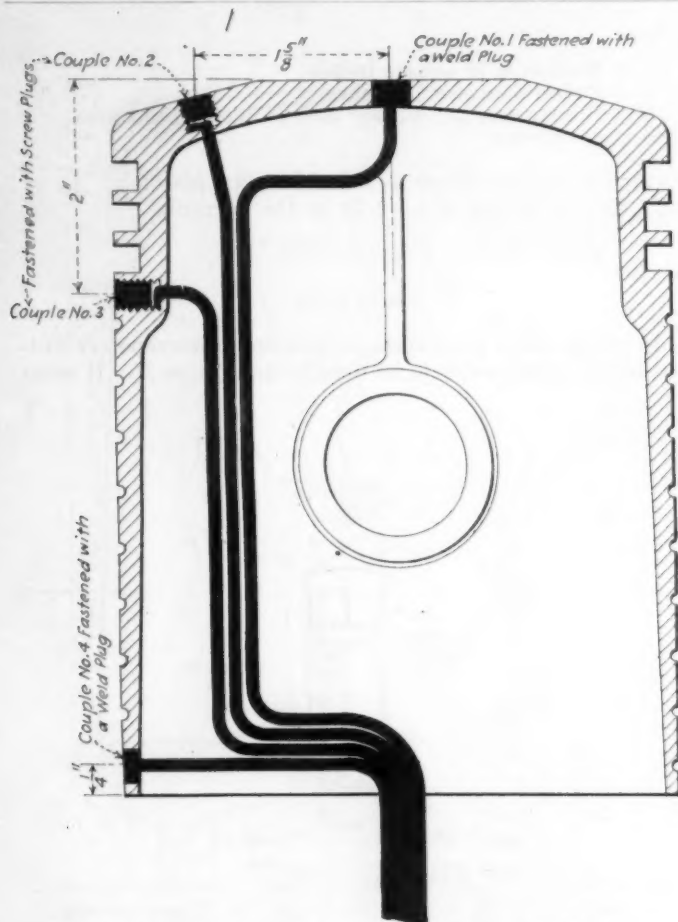with a Detail of the Channels for the Piano Wire Leads Underneath

FIG. 3—ARRANGEMENT OF THERMOCOUPLES IN THE PISTONS

also be borne in mind that the minimum thickness of the head or the wall depends on foundry practice and will vary for individual cases. It is therefore best to consult with the foundry on this subject.

OPERATION TEMPERATURES OF PISTONS

Several years ago we conceived the idea that much could be learned by actually measuring the temperatures of pistons in operation in an engine. For this purpose a single-cylinder Liberty engine was utilized. It was thought best that some means should be provided for conducting the thermocouples out of the engine without subjecting them to any bending whatever. To accomplish this it was necessary to run a straight tube from the piston down through the crankcase. Due to interference between this tube and the standard crankshaft and con-

necting-rod these parts had to be redesigned. This required much time, and it was not until about a year after the design was made that the first tests were started.

A general layout of the apparatus in its early stages is shown at the left of Fig. 2. The couples terminated at the cold junction point shown in the diagram and the leads from there to the potentiometer were made of piano wire. This arrangement looked very promising for a while, but it was too heavy and the fastening connecting the piston to the tube was broken. It was then decided to eliminate the pantagraph arrangement and let the piano wire form the connection between the cold junction and the potentiometer unsupported. To eliminate vibration of the wires as much as possible they were placed in narrow channels which permitted motion in only the vertical plane. The upper right portion shows this set up while a more detailed arrangement of the channels is given underneath.

Fig. 3 is a diagram of the pistons showing how the couples were attached and their location. Couple No. 1 is in the center of the head, No. 2 is on the intake side at right angles to the plane of the wrist pin, $1\frac{5}{8}$ in. from the center of the head, No. 3 is on the intake side below the rings, 2 in. from the top of the head, and No. 4 is located $\frac{1}{4}$ in. from the bottom of the skirt, also on the intake side. Several methods were used at different times for fastening the couple to the piston and two are shown in Fig. 3. The first one was to drill a comparatively large hole about $\frac{1}{4}$ to $\frac{3}{8}$ in. in diameter partially through the piston and a small hole the rest of the way. The couple was inserted through the small hole and bent over as shown, and a plug screwed tightly against it. This gave very satisfactory results. The point was raised, however, as to whether or not the plug had a sufficiently good contact with the rest of the piston to insure that it was not hotter than the piston itself. To investigate this point some of the couples were inserted in a similar way to the one outlined except that instead of inserting the screw plug the large hole was closed by welding. This was a rather difficult weld to make but those pistons in which the weld stood up showed no difference in temperatures over those using the screw plug. In all cases the head couples were inserted 1/16 in. from the inside of the piston.

The results of the piston temperature tests given below are not considered as final but are sufficiently conclusive to indicate the temperature distribution in pistons. The first tests were made with a piston designed according to the Hall formula mentioned above. Even the preliminary tests made with these first pistons showed that
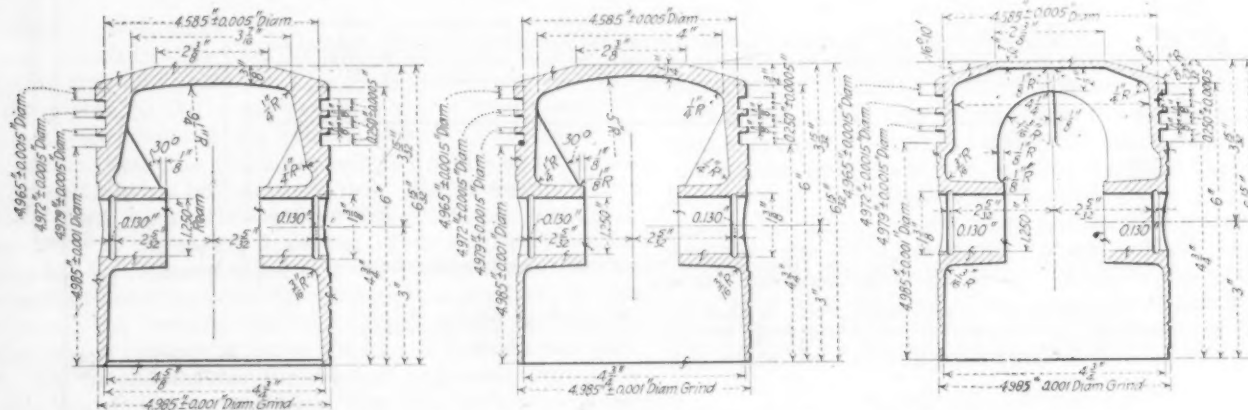

FIG. 4—SECTIONS OF THE THREE PISTONS USED IN MAKING THE TESTS

the heat did not follow the outlined path to the water-jacket. The greatest temperature drop was noted between couples Nos. 2 and 3, that is through the rings, while the drop through the skirt was not as large as that through the ring section. At this point we would like to bring out the similarity between the results obtained by Arthur A. Bull of the Northway Motor & Mfg. Co. and ourselves, although Mr. Bull's work was done on a stationary piston in a water-jacketed cylinder.

It was then decided to make up several pistons of different thicknesses and constructions and note the difference in temperature distribution. Fig. 4 is a set of detail drawings of the pistons that were used. The amount of metal in each one is best expressed by the weights, which are, from left to right, 3.9 lb., 3 lb. and 2.5 lb. Since it was not certain that the apparatus would work at high speeds it was thought best to make all of these tests at 800 r.p.m. or as nearly that speed as possible. Fig. 5 shows the results obtained from these tests on the different pistons, the figures around the outline indicating the temperature at the various points and the drop between them. The average speed of all the tests was 800 r.p.m., the average brake horsepower 13, and the average cooling-water temperature, inlet, 126 deg. fahr. and outlet, 147 deg. fahr. In the piston at the left which was the heaviest, the drop across the rings was 280 deg. fahr. and the drop across the skirt only 105 deg. fahr. In the next lighter piston which is shown in the center the drop across the rings was 349 deg. fahr. and the drop across the skirt 43 deg. fahr. In the lightest piston tested, that at the right, and which incidentally had two cross ribs, the drop across the rings was 394 deg. fahr. and the drop across the skirt was 83 deg. fahr. It is interesting to compare these results and at once it becomes apparent that in spite of any section we can put behind the rings and on the skirt the greatest temperature drop is across the rings. It is therefore very obvious that the origial Hall idea of by-passing the rings is not absolutely correct. It is just as apparent, however, that the amount of metal behind the ring grooves does affect the temperature drop. Comparing the three pistons we find that the drop across the rings is less when more metal is used behind them.

Calculating a wall area based on the power developed by the engine at this speed we would get an area slightly less than the one shown at the right of Fig. 5. It would therefore seem that the formula developed for wall area does not call for too much metal, in fact slightly more would do no harm. The piston mentioned is a trifle on the thin side for mechanical reasons and more metal should be added on that account. The formula for wall area behind the rings should, therefore, for the present at least, be adhered to. The results would seem to indicate, however, that it is not necessary to have as much metal immediately below the rings or in the section e-e in Fig. 1. The skirt thickness should therefore be determined largely by casting, machining, and other mechanical requirements.

The next interesting point to be considered is the temperature of the head. Unfortunately more trouble was encountered with the couple in the center of the head than with the other couples used and in the one case, that of the piston at the right of Fig. 5, no successful reading was obtained. By comparing the other pistons, however, we can see that some difference can be laid to the thickness of the head. A difference of 32 deg. fahr. was recorded between the center head temperature of the pistons at the left and center. The temperature toward

	Speed, r.p.m.	
800	800	800
	Brake horsepower	
12.9	13.1	13.2
	Inlet Water Temperature, deg. fahr.	
128	126	126
	Outlet Water Temperature, deg. fahr.	
148	145	147
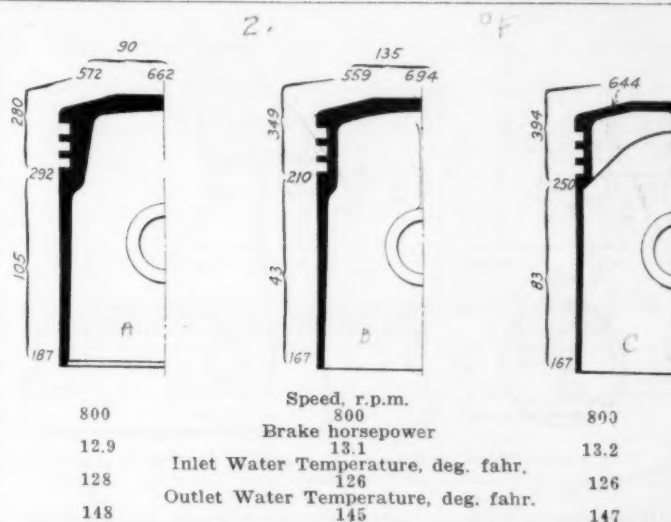
FIG. 5—RESULTS OBTAINED FROM TESTS OF DIFFERENT PISTONS SHOWING HOW VARIATION IN THE DESIGN AFFECTS THE TEMPERATURE IN OPERATION

the side of the head as measured by Couple No. 2 was actually a few degrees higher in the thicker piston. This can be explained in three ways, (a) the difference of 12 deg. fahr. is possibly as close as any two pistons of the same design would operate, (b) it may show that for the amount of horsepower developed the central piston had a head of sufficient thickness, and that a greater thickness would not be of any benefit, and (c) the temperature difference across the thinner head would naturally be greater than that across the thicker head. Couple No. 2, in the lightest piston shown at the right of Fig. 5, however, was 72 deg. fahr. hotter than the similar temperature for the piston at the left. That, without a doubt, is due to the head thickness. According to the formula the first of these two pistons had a head thicker than necessary, but the temperatures obtained would seem to indicate that it was not too thick. If more taper had been used, that is, if the head had been made thicker where it joins the skirt the temperature of 644 deg. fahr. would have been reduced somewhat. Until such time as further work can be done it is wise to adhere to formulas
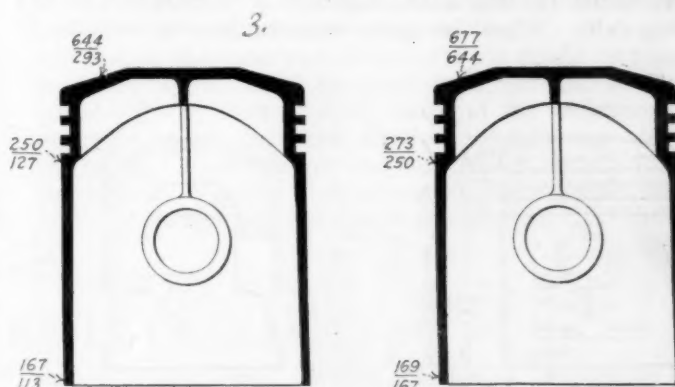
The Upper Temperature Readings Were Obtained at a Speed of 800 R.P.M. and Brake Horsepower of 13.2 and Inlet Water Temperature of 126 Deg. Fahr. and an Outlet Temperature of 147 Deg. Fahr. The Corresponding Values for the Lower Readings Were 800 R.P.M., 14.0 B. Hp. and 48 and 58 Deg. Fahr.

The Upper Temperature Readings Were Obtained with a Speed of 1000 R.P.M. and 16.2 B. Hp. and the Lower with a Speed of 800 R.P.M. and 13.2 B. Hp. The Inlet Water Temperature Was 126 Deg. Fahr. and the Outlet 147 Deg. Fahr. Throughout

FIG. 6—TEMPERATURE DIFFERENCES DUE TO AT THE LEFT A VARIATION IN COOLING WATER TEMPERATURES AND AT THE RIGHT A CHANGE IN SPEED

FIG. 7—A PISTON USING A SLOT TO COMPENSATE FOR THE EXPANSION
OF THE HEAD

outlined above because passenger-car pistons designed in
that way have given good results.

COMMENTS ON THE TESTS

In making these temperature tests other troubles were
encountered besides the mechanical workings of the
parts. It was discovered that piston temperatures, espe-
cially that of the head, were very susceptible to changes
in fuel consumption. A sufficient amount of data has
not been collected on this subject for presentation in this
paper but we can state that it warrants further investi-
gation. All the tests reported herein were made with
the same fuel consumption.

It was also discovered that changes in cooling-water
temperatures brought about a marked difference in the
piston temperatures. The temperature at the lower end
of the skirt is dependent, largely, upon the temperature
of the cooling water. Sufficient time was not available to
go into this problem as thoroughly as would have been
desirable but enough data were collected to show the
effect of an extreme change in water temperatures as
shown at the left of Fig. 6. Unfortunately these tests
were made on the piston in which the center head couple
was inoperative. Couple No. 2 on the head, while the
inlet cooling-water temperature was 126 deg. fahr. and
the outlet 147 deg. fahr., indicated a temperature of 644
deg. fahr. When the water temperature was reduced to

FIG. 8—IN THIS PISTON THE MECHANICAL EXPANSION DUE TO THE
HEAD IS TAKEN CARE OF BY RELIEVING THE SIDES

48 deg. fahr. for the inlet, and 58 deg. fahr. for the out-
let, this temperature dropped to 293 deg. fahr., that is it
dropped 251 deg. Couple No. 3, below the rings, showed
a drop of from 250 to 127 deg. fahr., or 123 deg., for the
same change in cooling-water temperature. Couple No.
4 at the bottom of the skirt fell from 167 to 113 deg. fahr.
It is also interesting to note that the drop across the
rings decreased from 394 to 166 deg. fahr. and that
across the skirt from 83 to only 14 deg. fahr.

Due to a lack of time it was not possible to study
thoroughly the effect of engine speed on the temperature.
The right half of Fig. 6 gives the result of one set of
tests made at 800 and 1000 r.p.m. The water temperature
of both tests was held at 126 deg. fahr. for the inlet, and
147 deg. fahr. for the outlet. The horsepower at 800
r.p.m. was 13.2 and at 1000 r.p.m. it was 16.2 hp. The
head temperature was increased from 644 deg. fahr. at
800 r.p.m. to 677 deg. at 1000 r.p.m., an increase of 33
deg. The temperature below the rings was increased
from 250 deg. fahr. at 800 r.p.m. to 273 deg. at 1000
r.p.m., an increase of 23 deg. The temperature of the
lower end of the skirt remained the same; the increase of
2 deg. from 167 to 169 deg. is not outside the limits of
error. Judging from the results so far obtained the
speed has little effect on the skirt temperature. Before
stating this definitely more tests should be run and such
tests are contemplated.

CLEARANCE REQUIRED

As shown by the tests much of the heat leaves through
the rings. The temperature immediately below the rings
is at times several hundred degrees lower than the head
temperature. Since thermal expansion is a function of
the temperature it would seem, offhand, that this state
of affairs would be ideal. We know, however, that the
clearance required for aluminum pistons is much in excess
of that necessitated by skirt temperatures. There can
be only one explanation of this and that is, that the hotter
piston head will cause a mechanical expansion of the skirt
in addition to the thermal expansion due to its tem-
perature. The force set up in a structure due to its
temperature is really enormous, as a simple calculation
will show.

Modulus = Unit force ÷ Unit deformation

then

Unit force = Modulus × Unit deformation
Modulus for aluminum = 10,000,000
Unit deformation for 1 deg. fahr. rise = 0.000012 in.

Substituting

Unit force = 10,000,000 × 0.000012
           = 120 lb. per sq. in. per deg. fahr.

Bearing in mind that the difference between the skirt
and head temperatures is at times several hundred
degrees we can get some idea of the magnitude of this
force. There can, therefore, be no question that the
expansion of the head is accountable for much of the
clearance which must be given to the skirt of a piston.

If the skirt could be entirely separated from the head
the clearance could be greatly reduced. It is not prac-
tical, however, to separate the head entirely but it can
be separated from certain portions of the skirt so as to
relieve the skirt of mechanical expansion in certain direc-
tions. The most reasonable place to reduce the expansion
in this manner is across the thrust faces. A saw slot
immediately below the lower ring on both the thrust
faces will bring about this condition. The mechanical
expansion of the skirt in the direction of the axis of the

wrist pin will remain unaltered and some means must be provided for making this expansion harmless. This can be done by relieving these faces for their entire length or providing some flexibility by a slot. Both methods have been used and have given satisfaction. By separating the skirt from the head we eliminate mechanical expansion in one plane, that is across the thrust faces. Supposing we consider a piston with its head and skirt separated as just mentioned, running under conditions such as were shown in some of the temperature charts, with an average head temperature of 600 deg. fahr., a rise of 530 deg. above room temperature, the expansion of the head would be 0.032. The skirt temperature in this same test was 210 deg. fahr., a rise of 140 deg. above room temperature. This on a 5-in. piston gives an expansion of 0.0085 in. The mean cylinder-wall temperature is the average between the piston-skirt temperature and the cooling water, that is 178 deg. fahr., 108-deg. rise over the room temperature. This would give a cylinder-wall expansion of 0.003 in. The clearance necessary should then be the difference between the piston expansion and the cylinder expansion, which in this case is 0.005 in. This would give us no clearance for an oil film and the piston would seize. Tests which we have made prove that 0.005 in. is enough for a piston of this description running up to 1600 r.p.m. at which the skirt temperature is undoubtedly somewhat higher than at 800 r.p.m. The clearance which we know is necessary for the piston is less than the temperature would seem to indicate. This can be explained in the following way: The expansion of the head is acting on that portion of the piston skirt which is not separated from the head by slots and is imparting to it a mechanical expansion in addition to the thermal expansion. If a circle is expanded only along one diameter it will have to contract along the diameter at right angles to it, that is the circle will be changed into an ellipse by shortening one of its axes and lengthening the other. The mechanical expansion along the axis of the wrist pin has been made harmless by either relieving the piston at the ends of the wrist pin or by giving it flexibility by a vertical slot.

Fig. 7 shows a piston which makes use of the flexibility by means of a slot to correct for head expansion. This type is in use in the Maxwell car. Fig. 8 shows a piston in which the head is separated from the skirt on the thrust faces and the mechanical expansion due to the head is taken care of by relieving the sides as shown. This type is in successful operation in Northway engines. In making slots it should not be overlooked that these should be made as wide as possible so as to allow a free passage of the oil back into the crankcase. In providing
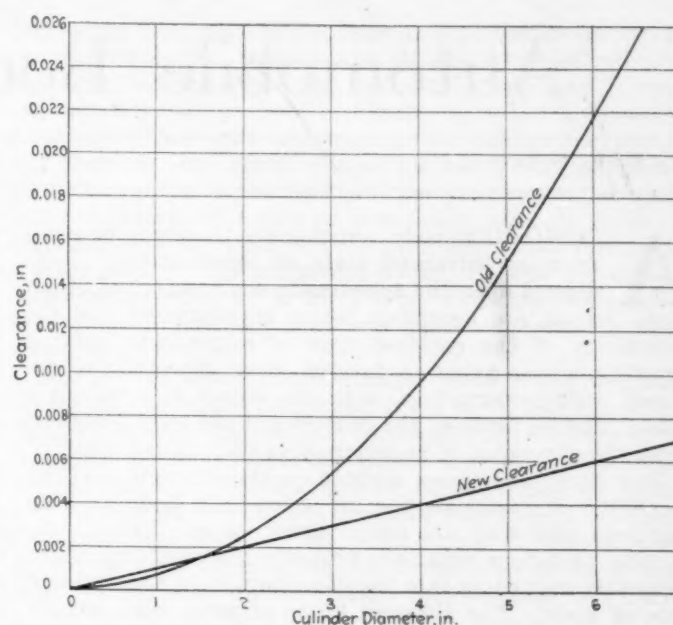

FIG. 9—COMPARISON OF THE CLEARANCE FORMERLY USED ON ALUMINUM PISTONS AND THAT NOW PREVAILING

a relief on the sides this should be of ample depth. Holes of a large size or preferably a short slot at the bottom of the relief should be provided so that oil accumulated in the relief can pass away easily and quickly.

The successful operation of pistons is measured by the minimum clearance necessary for satisfactory performance. The progress of aluminum pistons within the last few months can be shown best by comparing the clearance curves in use now with those in use several months ago. Fig. 9 shows these two curves, both of which are based on experiments. The top curve shows the clearance necessary for pistons of the old conventional type and the lower the clearance necessary for the types just mentioned.

It is, of course, impossible to lay down this curve as a definite law. Engine temperatures undoubtedly depend on engine design and piston temperatures depend upon piston clearance. While these curves were determined from actual practice the characteristics of all engines may not be the same and some variation might be found necessary. The actual clearance required can be determined only by tests in each case but the clearance on the curve represents a safe starting point for these tests. In the past aluminum pistons have shown certain faults but present practice indicates that these faults were faults of design and not faults of alloys.

AGRICULTURE IN CHINA

NEXT to America China is the greatest agricultural nation on the face of the globe. China's tremendous population of 400,000,000 souls is intimately and closely connected with the soil. Of China's $1,000,000,000 foreign trade in 1919 more than 80 per cent consisted of agricultural products or products which were all more or less closely associated with some form of agriculture.

In China farming is on a gardening basis. Practically all Chinese farmers own their land, but they do not own much land. In the densely populated coastal plain and Yangstze valley, an average Chinese farm is about the size of an American acre and this is probably a liberal estimate. Cultivation is intensive and it is not unusual to see three or four crops such as cotton, beans, cabbage and corn all growing on the same patch of ground, not separate plots, but "between the rows."

Although the Chinese farmers have worked out their own methods of land fertilization that have kept their soil fertile for 4000 years, they have not developed their farming implements. Chinese plows, hoes, rakes and harvesting implements are of the vintage of the year one or possibly, to be more exact, the pyramids of Egypt. The beast of burden in south and central China is the carabao or water-buffalo. In north China, Manchuria and Mongolia it is the mule, pony and sometimes the ox and camel.—J. B. Powell in *Farm Implement News.*

Automobile Body Construction

By P. E. Stone[1]

AUTOMOBILE body construction is about to enter upon an advanced state of development. Sales depend upon the appearance and comfort of motor cars, chassis are becoming better standardized and the popularity of the enclosed type of automobile body is growing. This paper is devoted more especially to enclosed body construction, with the object of creating a closer relation between the chassis and the body designer, from the viewpoint of an automotive body constructor.

Few books have been written on the strength and desirability of materials for an automobile body and its members, and they are not of great value. I shall enumerate, therefore, what are probably the most important materials that enter into the construction of the enclosed type of body. The different kinds of wood used include ash, yellow poplar which is commonly misnamed white wood, birch, maple and the cheaper kinds, depending upon the grade of body that is to be built. Aluminum of Nos. 14, 16 and 18, B. & S. gage is employed; this is 98 per cent pure aluminum, one-half hard. Steel, of automobile body drawing ductility and of Nos. 20, 22 and 24, B. & S. gage, is utilized. Very little long terne or lead-coated steel is used for body purposes. Cast aluminum is sometimes used. Plywood and composition material are the most important of the less used materials. Plywood was used considerably in automobile body roof construction several years ago.

The most important of the glues is hide glue, some of which is treated for moisture proofing. Others are casein, blood-albumen and fish glues. The casein and blood-albumen glues are considered the best, but as yet they are not entirely dependable and must be mixed and used by an expert.

The Proper Seasoning of Wood

The piling and drying of lumber is especially important in connection with body construction. The lumber should be piled with great care from the time it is green until it goes into the final assembly of the body. Lumber often is piled in a damp place, or upon an uneven foundation, or is not properly spaced. If piled solidly, an unevenness often develops and a twist or wind is given to the board. This results later in a permanent set which can be remedied only by properly steaming the piece in a dry kiln at additional expense. With proper care used in piling and proper foundations and spacers of equal thickness on each tier, one placed directly above the other, a great saving is effected and a better product is secured. If boards have a permanent set that has not been relieved, they will be undersize when dressed or, if sprung into shape, a twist will eventually result in the member in which such a board is used.

Let us consider the methods of seasoning wood. Lumber salesmen will say that air-dried lumber is bone dry. In certain parts of Mexico, air-dried lumber means lumber that has come to the condition of the surrounding air. It will show a moisture content of about 5 per cent by weight. Again, in certain parts of the United States, air-dried lumber will contain 20 per cent of moisture.

Therefore, if an automobile body which has been manufactured of air-dried lumber in a moist climate is sent to some locality in a dry climate, the lumber will shrink from 3 to 5 per cent across the grain. Hence, any bolts which have been used in its construction probably could be tightened one or two turns, depending upon the thickness of the material and the thread size. As soon as a bolt becomes loose, it causes a creak in the body, paint cracking and chipping, and other general troubles.

The dry kilning of lumber probably is the most important phase of lumber seasoning and it is also just as delicate an operation as the hardening of steel. Very little is known generally about dry kilning. When lumber is properly dry kilned and is not killed during the process, it is probably stronger and of a more uniform moisture content than lumber that has been air dried in the pile. After considerable experience in manufacturing airplane propellers, I think that lumber dried to a moisture content of from 8 to 10 per cent will give the best results for all conditions of atmosphere, because the moisture which is absorbed after the wood has once been dried is not so detrimental as the shrinkage. Probably, only a small percentage of the dry kilns used in automobile-body building plants could pass the Government specifications for dry kilning. Very many of the automobile body builders are still using the old fashioned hot or dry box. A pamphlet entitled Information for Inspectors of Airplane Wood, prepared at the Forest Products Laboratory of the United States Department of Agriculture, is available for those who are interested in the proper drying of lumber.

Metal Bodies and Construction Features

All-metal or steel bodies are made only for open-car types. Very little all-metal or steel construction has been developed as yet for enclosed bodies, owing to the fact that many things, such as tacking rails for upholstery and window regulators, are required which necessitate using wood. Further, enclosed bodies have not been built in large enough quantities to warrant the expensive dies which would be necessary for all-metal construction.

With regard to the actual construction of automobile bodies, the day has past when the woodworker in the body shop was given an outline draft, selected the stock from the lumber pile, made his own patterns, located the mortises and tenons and used the band saw, planer and other machines, completing the whole process himself. Today, the draft must be made so that the mill can get out the stock without seeing the draft as a unit; also, the shapes of each piece must be changed sufficiently to allow the mill machinery to reproduce it without too many separate operations and set-ups. These pieces must be constructed so that they can be assembled into units, such as backs, quarters, doors and roofs, and can finally be put together without a great amount of fitting. In fact, the draft as a whole does not leave the draft, pattern, layout and dressing-box rooms. Each man in the shop does only his own part. Where only two men touched a body in the body shop under former condi-

tions, 25, 50 or more, may participate in its construction at present. This specialized construction is and has been developing many new machines for the mill. It also places a certain handicap upon designing. The methods of construction have been changed completely within the past 10 years.

In body construction, the draftsmen should have not only careful and accurate measurements of the chassis, but they should know the maximum amount of deflection, plus and minus, of the chassis frame from front to rear. They should know also the amount of wind or twist of the chassis. Neither of these factors have ever been defined, to my knowledge, but the construction has to be made so as to take care of both. This lack of necessary information has caused much trouble. It has produced body creaks, rattling doors, excessive up-and-down play of the doors and the opening of body seams.

CHASSIS DEFLECTION

When you ride in a car with an open body with the top raised and are badly jolted you sometimes hear the material of the top snap. This is good proof of whether a chassis frame twists or deflects. The top first loosens and then snaps tight. This is more in evidence when the top is of the old cape type. Also, the doors move up and down. In a rigidly constructed body with roof rail, the body must withstand all of these strains. Again, the chassis designer fixes the steering column both to the chassis and to the instrument board in the body, which is placed 24 to 36 in. further back on the chassis frame. Strike a rut and the frame deflects; the instrument board creaks and twists, or the steering column bends, otherwise there must be a very rigid construction that ties these three parts together. If the chassis frame deflects down and then up, a tension or a compression force is set up in the roof rail because the center of bending is either above or below the frame. In most of the slanted fronts there is a triangular support which does not allow the front pillars to bend. This either directs all the thrust to the back of the body or transfers the thrust down into the cowl. It is more than likely that this thrust causes many cowls and front pillars to give trouble above the belt on coupés, sedans and four-door inside-drive bodies.

In fastening a body to a chassis frame, sometimes the body sills are placed directly on the frame. The body may be fastened on angles or lugs, three or four to a side, and from 2 to 4 in. from the outside of the frame. This introduces a third strain on the body, as there is a slight twist introduced into the side member of the frame which results in a twist of the body sills. The argument in favor of this method is that it eliminates the squeak between the body sill and the chassis frame, but the mounting of the sill directly above and on the frame, with proper separating material, will usually give the best results. These are a few of the difficulties, but they are beyond the control of the body engineer.

With regard to the constructor's difficulties, let us first consider the body as a mass, concentrated at one point. Such a point would be located from one-half to three-quarters of the length of the wheelbase from the front and from 36 to 60 in. from the ground, dependent upon the style, size and shape of the body. If the front wheel strikes an obstruction, although part of the shock is absorbed by the rubber tires and part by the chassis springs, there is still the inertia of the body as a unit to overcome. Since the force is dependent upon the speed as well as upon the mass, enormous strains are exerted in the joints of the body at high speeds on some rough roads. This force can be divided into vertical and horizontal components. The horizontal component is the one which produces serious effects upon the body construction. The cowl and wind shield are at the front and there is very slight chance for heavy or rigid construction, owing to the fact that the driver must have as much unobstructed vision as is possible; also, the pillars, from the belt up, tend to bend and they must overcome a large part of this horizontal force. If it is a slanted-front construction of a rigid type, this force is transmitted down into the cowl and causes squeaks, rattles and cracked panels.

One way to lessen this horizontal force is to lower the center of the mass and make the roof construction as light in weight as possible. On straight front bodies, it is a good method to taper the pillars from 1 to 3 in. from the belt rail up. On slanted front bodies it is good practice to provide a rigid construction and have a member following the angle of the wind shield to the chassis frame as near as possible. It is possible to have the front of the body strong enough to withstand this horizontal force, and the reaction may be transmitted to the back of the body and cause open joints.

DEVELOPMENT POSSIBILITIES

There is considerable opportunity for development along the following lines. Springs should be designed to allow the same elasticity for two as for seven passengers. This would result in less strain on the body. Hard, stiff springs shake and jar body joints. The frame might possibly be designed with a subframe of the full body width at the outside of the sills, cross-braced not only to support the transmission but to eliminate as much twist and wind as possible. At some future time we may build the body and the frame as a unit, possibly using I-beams instead of channel irons.

The progress that is being made in automobile body construction includes a heavier cowl construction, together with the use of heavier gage aluminum and more spot-welding or reinforcements. In the larger body plants great care is being used in drying lumber. Roofs are being constructed that are lighter in weight and of materials that will cause less drumming, or resonance. Slat construction is used in many different forms; it is covered with woven material or leather. The trouble found with plywood, when used for roof construction, was due to the fact that there was a large amount of resonance caused by the movement of the wheels on the road, which tired the ear drums of the passengers. Metal roofs were subject to the same rumble and it developed also that extreme heat would cause a slight expansion of the metal and allow the roof to rattle. Much experimenting is being done with different types of cushion spring construction. Curtain rollers have been improved, but locks, door bumpers, door strikers and the like, have not advanced to any great extent since the construction of automobiles began, although some slight improvements have been made.

I think that body construction will not be changed radically until either the basic type of design or shape is transformed or there is a firmer foundation to build upon. Today, all types and styles of body, from the two-passenger open-type to the seven-passenger enclosed-type bodies, are built upon the same foundation base. When we have different frames, and this will be only through evolution, much of the weight, rattle and noise of the enclosed automobile body will be eliminated.

THE DISCUSSION

E. W. M. BAILEY:—I wish to call the attention of automotive engineers, especially chassis men and the men who are not body builders, to the twisting effect of the chassis upon the body. I have had some experience in building automobile bodies, and I cannot see why any enclosed body does not go to pieces. I have had trouble with some that did go to pieces. In one case we insisted that the chassis maker use a deeper frame because the deflection was so great. There has been no real remedy suggested.

I ask automotive engineers, salesmen and automobile men generally, not to be too conventional. When the horseless carriages came out they were very unconventional. When the engineer came out with a new idea, it was accepted if it was right, no matter how it differed from the conventional. But, my father said that in the days of the coach and carriage builders they were not allowed to do unconventional things. Our American coach builders really copied the designs of the French and English, which were very heavy. No man was allowed to build a light coach body of the enclosed type. The buggy builder, however, designed a purely American vehicle and it was made to carry ten times the passenger or vehicle weight that the coach carried.

In enclosed body building the chassis must twist. This means that the body must give or else the body must help support the chassis. Both things happen in practice. If the chassis sill is bolted down throughout the whole length of the frame, it undoubtedly strengthens the frame to some extent.

Weight is a serious thing for the automotive engineer. These things are all related to each other. The weight of a limousine body might be as stated from 1500 to 2000 lb., but that is a little heavy according to my experience. Even 1200 or 1500 lb. is considerable weight to carry around. I have had experience with the electric automobile, where one could absolutely measure the power required to move the car. Our power was cheaper than gasoline, but we naturally wanted to economize it. With voltmeters and ammeters we could measure the power accurately. If a difference of 10 to 15 lb. would show in a 2000-lb. electric car as it did in our tests, it certainly affects the performance of a gasoline car.

In the matter of the chassis and the body twist, we must either arrange some kind of three-point suspension or a separate frame, so that the body need not carry the chassis frame; or, we must devise a construction so that the body can move with the chassis without wrenching itself. Either of those things is possible if we disregard conventional ideas. If an enclosed body were constructed in a very different way so that these things could be done, probably it would be termed a freak. The construction of the enclosed body is highly conventionalized. There are some 350 pieces of wood in the frame of a limousine. Every one of those pieces is named; the sill, the pillar, the rails, and even the minor pieces all have a name or are described by location. If a body is to be built as suggested, that conventional construction must be eliminated and I think it can be done.

In my electric car propositions, we made a phaeton body, an open phaeton like the horse-drawn phaetons that were very common at one time. We made a bentwood body that was 4 in. wider than any other and that weighed less than any of the others. It weighed less than 30 lb. and there was no other body that weighed less than 130 lb. If it could be done in that case, it can

be done in the enclosed body through the use of laminated wood or plywood; not used as a covering over of the conventional frame, but with an entire change of the frame. My father was, I think, the pioneer in the use of laminated panels in vehicles, the first one being of basswood, with linen between. Previous to that he made rotary-cut panels with a band saw. He sawed a log endwise in a spiral curve to the center, and then steamed the product and straightened it out. By this method we could make much thicker panels. We could cut ½-in. panels and straighten them out without causing checks on the outside. We could use a hard wood such as ash, oak or walnut, and get out panels 40 ft. long and 4 ft. wide that were all quartered grain. I have used plywood a long time. If the body is designed to utilize the strength of the plywood rather than the frame and we are allowed to do some other unconventional things, I believe that the weight of the enclosed body can be reduced certainly 50 per cent. I think we could reduce its weight 60 per cent or even more. If we could eliminate 500 or 600 lb. of weight that the chassis must support, think what this would mean in improved car performance. If 100 lb. of weight will show in the power required to move an electric car, certainly a saving of 500 to 800 lb. is of value to automotive engineers in gasoline propelled cars.

Regarding the curing of wood and the statement that a moisture content of 10 per cent is about the standard, Mr. Stone spoke about the effect of wood swelling and shrinking afterward when fastened. I have kiln-dried some millions of board feet of wood for bodies and have had most of the trouble with the wood in the factory. Some factory buildings are very dry. From the time the ground freezes until spring their atmosphere is absolutely dry. In the wholesale production of enclosed bodies it is necessary to pile up many thousands of pieces of body frame ahead of the bench worker who assembles the parts. If they were not very dry, that could not be done. I have dried most lumber down to 2 or 3 per cent of moisture content. With good apparatus and skilled men in charge of it the kilns will do that. Then we took the pieces into the shop and, after being band-sawed they would have time to come to the humidity of the factory. We never had any trouble on that score. For the benefit of body makers who work in smaller quantities, I would say that in the horse-drawn vehicle days, where we handled many thousands of pieces, we never kiln-dried a plank in our own factory. We blocked it out first to the rough dimensions, dried it almost to absolute dryness, brought it into the factory and let it rest there until it reached the humidity of the shop. It would do that in a week, in ordinary commercial quantities. You can dry a stick very much quicker and with less care than you can a plank or board. Band-sawed air-dried lumber can be dried successfully in a hot kiln; some moisture can be supplied if one pleases, but there is no apparent trouble from it at all in the small pieces. One cannot get case-hardening in a piece as small as a pillar; perhaps a sill would require some different treatment, but from a pillar down there is no trouble in drying ordinary quantities.

CHAIRMAN R. E. NORTHWAY:—It would appear that we must have either resilient bodies or three-point suspension frames.

P. E. STONE:—As to the weight of bodies, when I mentioned 1500 or 2000 lb. to the body I meant the weight as ordinarily equipped, with chassis equipment, tools and passengers. I spoke of 2000 lb. because that is really the weight which the body stands. The average weight of an automobile enclosed body today will vary from 700 to

1200 lb. and possibly one make of body would weigh about 1300 lb. without passengers. The statement is true about drying lumber to sub-normal shop conditions. Dry the lumber too low and let it come up in moisture content, rather than begin with too much moisture and lower it in the shop. When lumber is shrinking it checks; when it is absorbing moisture it does not check. Many large body-building plants are introducing thermostatic control to take care of the humidity in the winter. This is true also in furniture shops.

I have had considerable experience in drying panels. Plywood, when using the glue spreader, should be dried to a moisture content of about 5 per cent before the glue is applied; say 3 to 5 per cent for the core and shell. When it is finished and comes out of the dry kiln for the last time it has from 8 to 15 per cent of moisture; my experience has been to keep the dry kiln below 100 deg. fahr. temperature for best results, because there is less internal strain in the cores. If the temperature is raised too much with low humidities, there is a certain expansion of the core, which is laid opposite the grain of the shell; lower temperatures and rapid circulation of air will give very good results. Thicker panels should not be taken out of the dry kilns until the temperature of the kiln and the plywood has come down to that of the room.

Great trouble is experienced with veneer in roof construction. Formerly there were more veneer than plywood roofs. The shell and core were of different thicknesses in the old automobile body roofs. Several years ago when the dome shapes with sweeps from front to back began to be used, roofs were manufactured only by one or two companies in the United States who used a mold and built the plywood up to fit the double curvature from front to back with the proper sweep. These roofs came practically to shape, otherwise checking would have resulted. We covered these roofs with canvas and painted them. The great trouble with plywood in automobile body construction is to moisture proof both sides. If it is treated with anything to keep the moisture out, a good glue joint cannot be obtained. That is the only difficulty with plywood. If one can nail or screw it on, it is all right. But if a glue joint up against a pillar or something like that is wanted, there is difficulty in keeping the moisture away from both sides of the plywood. If the moisture gets at it, trouble results.

WILLIAM J. BAIN:—The statement that ox blood and casein glues had to be used by experts, applied several years ago, but it is really not true today. Casein glues really gained their prestige in the war, as was true of many other things. Casein and blood albumen are about the oldest adhesives known and are not a new discovery as many people think today. Ask any old fellow that has served as an apprentice in Europe, if he has ever used a "pot-cheese glue" for gluing outside work. Very likely he will say he has. This pot-cheese glue was a casein glue.

When the casein glues were first introduced into this country, they were shipped to the manufacturers in two parts. The manufacturer received the prepared casein and the other ingredients, and was given a formula for their mixing. He had a man in the plant who did nothing but mix this casein glue. Generally this man prepared much more glue than was required for the work on hand, and as the glue would not stand up for more than 2 or 3 hr., he would have to throw away about 50 per cent of the mixture, causing a loss of both time and material. This was a great objection to the casein glues. But since then,

the laboratories have been studying the problem, and they have now improved the casein glues so that the ordinary man in the shop can use them just as well as he uses the hide or other glues. About the beginning of the war the glue was put out in the form of a white powder; it was necessary only to add the proper proportion of water, agitate it for a few minutes and allow it to stand about 12 min. In about 15 min. after this powder is mixed with the water it is ready for use. It need not be used immediately, as the glue will stand in proper solution for about 12 hr. under ordinary conditions.

For all practical and commercial purposes the casein glues are waterproof and will stand up under any condition that they will encounter in the commercial line. An old foreman told me that he had used casein glue 40 years ago in Austria. He made tables that stood out in the open air in the Royal Gardens. Several years ago he went back there and found that those tables were just as good as the day they were made. Actual tests offer further proofs. Take a panel for instance, lay it up with casein glue, and allow it to dry for 48 hr. until the glue has arrived at its maximum set, and has attained its full waterproof qualities. The panel can then be boiled for 10 to 12 hr. and there will be absolutely no separation. It can be soaked in water indefinitely. I have soaked such panels until they have become green with mold. I could then twist such a panel into a spiral and there was no separation. A panel can be subjected to sufficient heat to char the wood, and the joints will not open up; in fact the joints are moisture proof and heat resistant at the same time.

For practical use in the factory the advantages of casein glue over other glues are numerous, in that they are waterproof and heat resistant, and are more economical to use in every way, both from price standpoint and spreading capacity. It covers from 40 per cent to 100 per cent greater space to the pound than hide glue. It is more easily prepared, being mixed cold and applied cold, and within 15 min. after mixing one can begin spreading the panels. There is no other glue on the market that can be prepared and used as quickly as this. Another feature is that the use of hot cauls and steam boxes is eliminated, and the glue room need only be kept at the regular temperature of the balance of the factory, say about 70 deg. fahr., and proper gluing can be done and the desired results obtained.

Mr. Stone referred to molded plywood tops. I have seen such tops molded, and these tops have been used for years, and they were put together with casein glue. Gluing operations in the factory did not have to be changed, except to eliminate heat as referred to before. The only special apparatus needed is a rotary mixer that will prepare the glue fast enough.

Various grades of casein glues are manufactured: there is a special grade for joint work, and another for veneer work. These special glues stay in solution for about 12 hr. A third grade used for veneer work is a glue that will take about 2½ lb. of water to every pound of glue; what is left at the end of the day is kept and mixed with the fresh batch next morning, so there is no loss. This is a new development since the war.

MR. STONE:—What is the rate of deterioration of the casein glues? What makes some casein glues soluble in water?

MR. BAIN:—The deterioration of casein glues is only relative, as glue mixed at 8.00 a. m. can be used until 6.00 p. m., but the next morning one would find an insoluble

mess in the glue pot which greatly resembled a custard.

The glues on the market at present include vegetable, fish, hide, blood-albumen and casein glues. Hide, vegetable and fish glues set by the evaporation of the moisture that is in them. Humidity or dampness causes them to dissolve again because they are just dried by the evaporation of their moisture content, but undergo no chemical change. With casein glue, as soon as the powder and the water are put together, a chemical action begins. This chemical action is very perceptible within the first 15 min. of mixing. The original mixture looks very much like a cooked cereal. After 15 min. its nature changes, and it runs in a free flowing liquid, very smooth and very similar to a heavy cream. The chemical action continues until the glue is absolutely hard.

In contrast to the hide glues, the older a casein glue joint becomes, the harder it becomes. The casein glue joint is also stronger with increased age. We have proved this by laying aside joints for 3 or 4 years and breaking them on a testing machine, in comparison with joints 48 hr. to 6 weeks old. The older joints showed the higher percentage of strength.

MR. STONE:—Some casein glues are moisture proof and some will dissolve the first time they are touched with water. What chemical action is lacking? Is it not true that one cannot be absolutely sure of the present casein glues?

MR. BAIN:—I can speak only from the standpoint of one casein glue that I have worked with and tested. I have samples that I have baked, boiled, soaked in cold water and all that. I cannot detect an opening on the joint. When I say that the casein glue I am talking about is absolutely waterproof, I mean that it is highly water resistant for commercial purposes; that is, if a panel is glued up and left to dry for 48 hr., it will not come apart within 2 or 3 hr. after being thrown into a tank of water, and will also undergo any of the tests mentioned before.

MR. STONE:—Are you sure that every batch of casein glue will be equal and alike?

MR. BAIN:—The firm I refer to has been manufacturing waterproof glue for 20 years. It manufactures its own casein, and has a laboratory in which everything that goes through for use in the glue is carefully watched and tested. Being manufactured according to a chemical formula, the casein glues are as consistent as they possibly can be, and can be depended upon. This consistency has been found in shipments of casein glues, which cannot be said of hide or other glues. As to what makes some casein glue water resistant and others not, that is a matter of chemistry and I do not know.

Casein waterproof glues when used in conjunction with plywood for automobile construction, will bring the cost down to a practical figure, and will tend to eliminate the shrinking and opening up of the joints, and can be used with a greater margin of safety on panel work, than vegetable or other glues. The blood-albumen glue panels are more waterproof than those of casein glue, but are high in relative cost, and are almost prohibitive for exclusive use in general body building.

Regarding the length of panels and the size of panels that can be rotary cut, this work is limited only by the length of the lathe and the thickness of the log. I have seen an oak log peeled, and the veneer ran off fully 125 ft. in length. This sheet was broken into 25-ft. lengths, and these laid over one another. They were then carried on an automatic conveyor to the slicer, where they were cut to the size of the panel desired.

MR. BAILEY:—To automobile body builders, this matter of slightly more or less waterproofness of glue is splitting it too fine. I can find sleighs with laminated panels made with hide glue that have been in use for 30 years and that are all standing up. Bodies are painted inside and out. If they are not so painted a waterproof glue is better, but if they are properly painted they will stand up anyway. We have glued thousands of panels with hide glue, using no screws or other fastening, and in quantities of them 10 years old the panels are not warped.

MR. STONE:—When I first started to build automobile bodies we were making them entirely of wood. We thought we could not make a back with a side panel and not have a molded covered joint. We have found out that this can be done. It was done with hide glues and on exposed joints; those hide glue joints are still standing up.

MR. BAILEY:—Is that under a good paint?

MR. STONE:—Yes.

CHAIRMAN NORTHWAY:—We need more definite information as to how to design and construct automobile bodies to meet road conditions and lighten the weight of the car.

C. H. METZ:—The problem is how to combine the body with the chassis. The two features which must be considered are the deflection of the frame member owing to the weight and strain placed upon it, and the twist that it is subject to on account of the unevenness of the road surface. I think it is not possible or desirable to build a frame sufficiently rigid so that all the twist can be eliminated. We eliminate the deflection caused by the weight, by building the frame section much deeper. I think the tendency is in that direction. A number of cars are being built now with frame sides 8 to 10 in. deep, which takes care of that situation very effectively.

The twist in the frame is a considerable problem and I think the frame is not the only member that must be considered in solving it. The tires take care of it to some extent. That matter is being solved in the right direction by using larger tires and ones that are more flexible. Tires are depressed by the amount of weight that is placed on them. An unevenness in the road causes the tire that goes into it to be relieved of some of the weight and the tire on the opposite side has an extra burden. Some of that unevenness is taken care of by the tire. Another member that takes care of more of this unevenness is the spring. Unfortunately, springs do not have a sufficient horizontal range to take care of all of the unevenness. There is opportunity for an improvement in springs, so that when one wheel goes into a hole the part that the tire cannot take care of will be taken care of to a considerable extent by the spring. In an extreme case, the frame will have to be flexible to some extent to take care of more of it. I believe we never will be able to pass it all along to the chassis. The body will have to carry some of the burden, and I think bodies will need to be made more flexible. If they are made lighter, they necessarily will become more flexible.

In considering this problem we must take all of these features into consideration. We should not attempt to remedy it by requiring any one feature to take care of all the mistakes. Our experience has been mostly with open bodies. We have built open bodies with the idea of taking care of a considerable portion of the twist in the body and have been fairly successful. In the line of enclosed bodies, with longer doors and the roof to take into consideration, they will have to be made flexible to a greater extent than has been true heretofore.

CHAIRMAN NORTHWAY:—We must consider the car as a whole. While we may have to come to having the body and chassis built as a unit, that does not work out as a good manufacturing proposition. Some of the best ideas in the world cannot be put into such shape that they can be successfully manufactured. We must look at car building not only from the point of designing but from the point of meeting the customer's approval and making a profit.

E. A. ROBBINS:—There are two examples of cars in which it appears that the designer has done something to take care of the twist. In the Ford car the frame is suspended from both ends, and the new Overland car is practically suspended from the front and the rear. Regarding deflection of the frame, I have a Ford car with a triangular body brace in front and a coupe body. When starting up a steep hill it buckles just at the front of the body. The hood vibrates up and down fully ½ in.

R. J. S. PIGOTT:—Considering the difficulties in overcoming the inherent strains in the body that are due to the rack or weaving of the chassis, it would appear that perhaps we are not paying sufficient attention to the design of the enclosed body as a box-girder whose joints are sufficiently stiff so that the structure acts as a unit rather than as a number of jointed members. As an instance of treatment of bodies in this manner, a more or less parallel case may be taken from railroad and trolley-car design. A few years ago, Mr. Stillwell devised a body construction for heavy electric interurban cars, which treated the whole body as a box-girder and practically eliminated heavy members such as sills and bolsters. The design of the one man safety-car has accomplished further progress along this line, since the body is used entirely as a chassis and there are practically no longitudinal channel members acting as a frame. The side wall of the car is treated as a deep girder. This is especially true in some of the latest designs, involving the extensive use of automobile materials and methods. It seems easily possible that we can not only average up the amount of distortion over the whole of the body, by making it act as a unit, but also reduce the weight very considerably.

Designers of automobile bodies must face the situation that no chassis, however stiff, can entirely eliminate weaving. Moreover, in a light-weight car, it will probably be extremely undesirable to eliminate entirely the effect of spring yield in the chassis. Therefore, the body designer is faced with two alternatives, either to suspend the body from three points or to design it so that its distortion will be equally divided at all places, such as the joints around the door openings and the cowl.

CHAIRMAN NORTHWAY:—I am acquainted with some men who are working along that line with plywood. Plywood suspension members for airplanes have already been mentioned and this man is attaching the springs directly to the body without any frame.

W. F. EADE:—In designing a car, the air head resistance should be considered in connection with the power required. If the car is of such a shape that the head resistance has been decreased to a minimum then the power required to drive the car can be reduced and a large heavy engine is not needed. The engine power required to overcome air resistance varies as the square of the speed, and one can readily see that a poorly designed car will consume more power merely to overcome air resistance and have less power left for tractive effort.

MR. ROBBINS:—Regarding streamline design for bodies of cars, I think we are not operating them ordinarily at high enough speed so that the form of the body has much to do with the air resistance.

MR. BAILEY:—The wind resistance increases as the square of the relative velocity. At 20 m.p.h. it runs into a lot of power against a 20-mile wind or at 30 m.p.h. against a 10-mile wind.

CRUDE OIL PRODUCTION IN 1920

THE preliminary report of the United States Geological Survey for the year 1920 gives domestic production of crude oil as 443,402,000 bbl. compared with 377,719,000 bbl. in 1919, a gain of 17 per cent. Imports of crude oil into the United States totaled 106,175,000 bbl. in 1920, compared with 52,822,000 bbl. in 1919. These added to the domestic production made the total "income" 549,577,000 bbl. in 1920 against 430,541,000 bbl. in 1919. There were added to the domestic pipeline and tank farm stocks in 1920 a total of 5,823,000 bbl. and to the Mexican crude oil stocks held in the United States by importers 4,523,000 bbl. The exports totaled 8,045,000 bbl. In 1919 there was added to the domestic pipeline and tank farm stocks 6,140,000 bbl. and the exports totaled 5,924,000 bbl.

Deducting the exports and additions to stocks from the total income the indicated total consumption of domestic and imported crude oil in 1920 was 531,186,000 bbl., compared with 418,777,000 bbl. in 1919. The indicated domestic consumption of domestic crude oil in 1920 was 437,579,000 bbl. against 375,559,000 bbl. in 1919.

The domestic pipeline and tank farm stocks held at the end of 1920 totaled 133,690,000 bbl. compared with 127,867,000 bbl. at the close of 1919. Figures on field stocks for 1920 and 1919 are not yet available, except a total of 3,423,276 bbl. covering stocks held east of California at the close of 1920. There was apparently a substantial increase in refinery crude oil stocks at the close of 1920. The latest figures of the Bureau of Mines as of Nov. 30, 1920, placed the quantity at 21,373,945 bbl., compared with 13,143,285 bbl. at the close of 1919.

Figures showing the crude oil record over the last four years are given in the accompanying tables, all quantities being in barrels. The figures are those compiled by the United States Geological Survey and the Bureau of Foreign and Domestic Commerce, except for the refinery stocks which are those of the Bureau of Mines.

INCOME AND OUTGO

Year	Domestic Production	Domestic Consumption	Imports	Exports
1920[1]	443,402,000	437,579,000	106,175,000	8,045,000
1919[1]	377,719,000	375,559,000	52,822,000	5,924,000
1918	355,927,716	380,242,153	37,735,641	4,900,691
1917	335,315,601	351,569,632	30,162,583	4,098,124

STOCKS OF CRUDE OIL

Year	Pipeline Stocks	Refinery Stocks	Field Stocks	Mexican Stocks in United States
1920[1]	133,690,000	21,373,945[2]	3,423,276[3]	7,442,000
1919[1]	127,867,000	13,143,285	[4]	2,919,000
1918	121,727,312	15,749,771	7,547,097	....
1917	146,041,749	11,638,433	13,705,811	....

[1]Preliminary figures subject to revision.
[2]As of Nov. 30, 1920.
[3]East of California.
[4]No figures available.

The German Submarine Diesel Engine

By Lieut.-Com. Holbrook C. Gibson,[1] U. S. N.

MUCH to the surprise of everyone present at the time of surrender, the German submarines came up to their moorings, maneuvering entirely by using their engines. This performance caused much favorable comment. An inspection was made of the various boats and in the majority of cases it was found that the engines were of Machinenfabrik-Ausburg Nürnburg (M.A.N.) four-cycle reversible type. A few other types were found, such as the Vulcan, Bolhm-Voss, Koerting, Benz, Nürnburg two-cycle and Krupp two-cycle but, comparatively speaking, they were very few in number. In our own submarine service, before the war we had heard
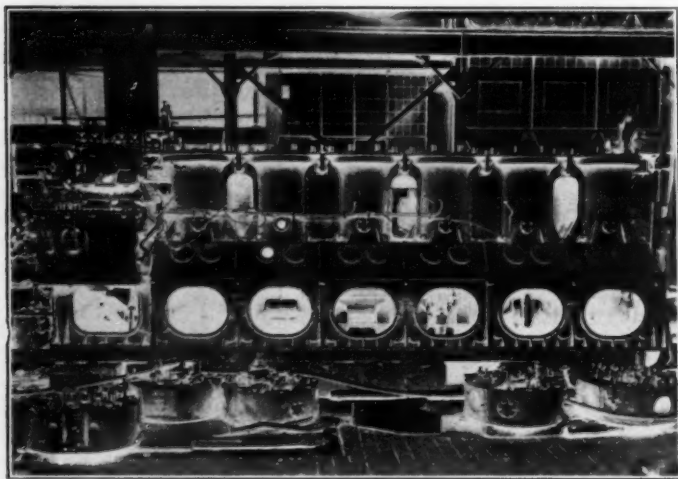
Fig. 1—Side View of a 1200-Hp. Diesel Engine Showing the Steel Construction of the Bedplate and the Housing Which Are Integral Up to the Base of the Cylinder Jacket

much about the Krupp two-cycle engine and naturally supposed that this was the best engine in Germany. However, the Krupp interests were so powerful at that time that they had had their engines adopted for the German submarine service. Out of about 183 submarines which I personally inspected at the time of the surrender, there were only five or six boats that had Krupp engines and they were out of repair. These engines also had one serious objection in that the cylinder-heads and some other parts were made of bronze, which metal became very scarce during the war. As soon as the war was well under way, the German authorities had to listen to the operating personnel and it became necessary to adopt the M.A.N. four-cycle engine, which can be considered as the standard for the German submarine. However, this type of engine was not a war product, but was a practicable proposition as far back as 1912.

During our inspection we found one submarine which

was fitted with a pair of M.A.N. four-cycle 800-hp. engines dated 1912. It was about that time that one of our own submarine officers was in Germany. He was shown practically everything in the Ausburg shops except a certain four-cycle engine which was in an enclosure undergoing shop tests. I have reason to believe that this was the engine type which was later adopted for the German submarine service, but it was not until after the war that this four-cycle engine became generally known. Nothing much was heard of it and what one did hear was very vague. Inspections of the German submarine flotilla and various submarine engines and engine plants in Germany revealed that the M.A.N. four-cycle engine predominated. It was being built not only by the Ausburg plant of the M.A.N. company, but at all the other engine plants. The M.A.N. engine is built in the following sizes: 100 hp. at 550 r.p.m.; 300 hp. at 550 r.p.m.; 500 hp. at 500 r.p.m.; 1200 hp. at 450 r.p.m.; 1750 hp. at 380 r.p.m.; and 3000 hp. at 390 r.p.m. The fundamental design of all these engines is the same, but as the size increases certain modifications are necessary. The bedplates are all of cast steel and so are the cylinder jackets. The cylinder-heads and pistons are of the usual material, close-grained cast iron. The crankshafts and connecting-rods are of good quality steel. The M.A.N. engine, with the exception of the 3000-hp. size, is made with six cylinders and an air compressor on the forward end which also carries the fuel pump and a device called the spray air regulator. Everything that is needed to run the engine is located at the forward end, available for the operator.

Regarding the 100-hp. engine, it happened that I went around Kiel harbor in the barge of one of the former German admirals. I noticed that the boat had a quick getaway and high speed. I looked into the engine room and saw that it had a 100-hp. M.A.N. Diesel engine just like the larger ones. This size is a practical proposition; it operated beautifully. This little engine had six cylinders and one three-stage air compressor on the forward end. The engine was air-starting and had a mechanical reversing gear through the clutch.

The 300-hp. type of engine had the same general design characteristics as the 100-hp. size. The pistons of the 100-hp. and the 300-hp. engines are not cooled. The 500-hp. size has six cylinders also and has additional features such as air-starting and reversing and two spray valves in each cylinder-head. In other words, it has a twin spray valve for fuel admission. The pistons are oil cooled in this size.

The unit developing 1200 hp. at 450 r.p.m. is exactly the same as the 500-hp. size; it has oil-cooled pistons and some variations in the type of air compressor. There seems to be no standard practice regarding the use of a three or a four-stage air compressor. In a mine-laying

cruiser one will find a four-stage air compressor and in another type of boat a three-stage compressor. In the former the compressor is used not only for the engine but for charging the air supply for the ship. That is the only difference in the 1200-hp. type. They are all the same and look as though they had been cut from the same pattern. The 1200-hp. engine can be considered as the German standard, since it was used in a great many vessels; their 800-ton submarine was the standard submarine. A German officer told me that if Germany had concentrated on this 800-ton submarine type, Germany would have won the war. I do not know the total number, but they built 200 or 300 of the 800-ton boats and each was equipped with the 1200-hp. engine.

GENERAL DETAILS OF CONSTRUCTION

Fig. 1 gives a very good idea of the steel construction of a 1200-hp. engine. The bedplate and the housing are integral up to the base of the cylinder jacket. The bedplates are made in sections to take in two cylinders and they are bolted together with many bolts, resulting in a very substantial construction. The joints can be seen in the illustration. There is a small section on the forward

FIG. 3—LOOKING AT THE FORWARD END OF THE 1750-HP. ENGINE

separators for the various stages of the air compressor. The wheel shown controls the reversing mechanism which is on the 1200-hp. engine and smaller sizes. It works very easily and one man can handle it without any trouble. This 1750-hp. is the type of engine discovered on the so-called Von Tirpitz super-submarine. These vessels run from 2000 to 2700 tons displacement and were built primarily to operate on the Atlantic Coast of the United States. The engine in the 2000-ton boat is of the 1750-hp. type. As is seen in Fig. 3, it has six cylinders, with air-starting and reversing gear. It has all the earmarks of its predecessors except a few radical departures in design.

Fig. 4 shows the 3000-hp. engine found on the 2700-ton boats which were the largest of the German submarines. It is practically the same as the 1750-hp. engine except that it has 10 cylinders instead of six. The picture of an average man standing alongside gives an idea of the size of this engine. All of the German engines are

FIG. 2—LOOKING DOWN ON THE 1200-HP. ENGINE

end for the air compressor. The cylinder jackets are also bolted to one another and go all the way across on the inside forming a regular girder construction; the result is a very rigid engine but, where it is bolted together, it is free to expand upward. In other words, the bolts that go through the section are not fitted but are loose, the cylinder jackets being able to expand upward.

Fig. 2 shows the engine viewed from above. The principal feature to be noted is the twin spray valve. In my opinion the idea of the twin spray valve was originated on account of the construction of the cylinder-head. If they had cut one big hole in the cylinder-head for the spray valve in addition to the large inlet valve opening, the cylinder-head would have been materially weakened. It looks complicated, but really is not and it works beautifully. The satisfactory operation is simply a matter of accurate workmanship and proper lining up of the valves.

Fig. 3 gives an idea of the mechanism at the forward end. This is the 1750-hp. engine, but it is practically the same except for one additional feature. The fuel pump, air regulator and air compressor are shown. There are three air coolers and below the coolers are the three
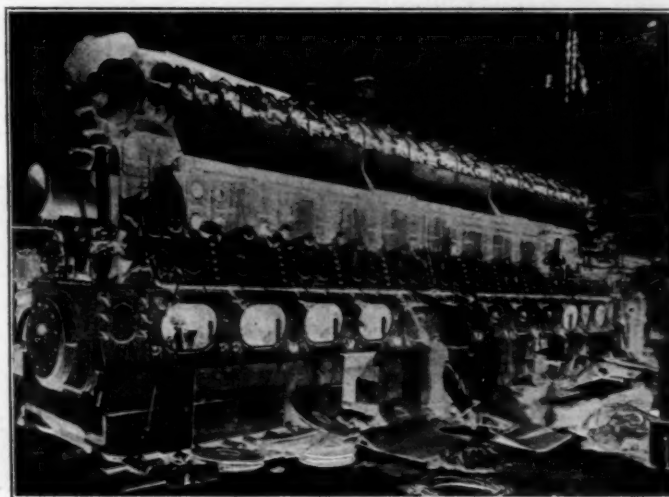

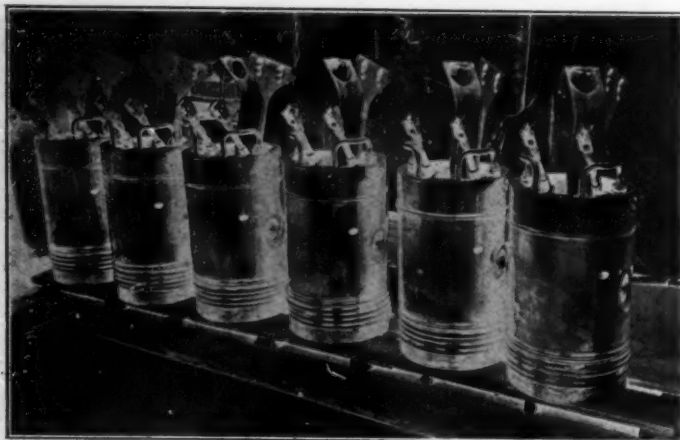FIG. 4—VIEW OF THE 3000-HP. ENGINE WHICH WEIGHS 14,000 LB.

FIG. 5—THE PISTONS OF THE 1750-HP. ENGINE REMOVED

comparatively light for their horsepower. The 1200-hp. engine, complete with exhaust heads, dependent auxiliaries and everything except miscellaneous piping and the oil cooler, weighs 57,000 lb. The 1750-hp. engine, complete with dependent auxiliaries, flywheel, exhaust heads and the like, weighs exactly 97,530 lb. The 3000-hp. engine weighs 72 net tons, or 144,000 lb. One can see in the illustration how the engine is bolted together; all the bolts fit loosely so that the castings are free to expand upwards, but not fore and aft.

Some radical departures are made in the construction of the pistons of the 1750-hp. engine. Fig. 5 shows the six pistons removed. From a casual glance one would think they were exactly the same as those of the 1200-hp. engine. However, when we commenced to clean them up and looked on the inside, we noticed a row of bolts. When these were taken out we discovered that they released the piston head. The pistons are a radical departure in design from their predecessors in other engines. Fig. 6 shows one of them taken apart; the trunk of the piston, with the flange at the top; the piston-head, looking inside; and the cover that goes up inside of the piston to make it a closed cavity so that the oil cannot escape. The piston head is a very fine piece of work. It is a block of semi-steel, machined inside and out. The cavities are for the cooling oil which comes in at the side, works its way around through these grooves and finally into the center and out. Locknuts are provided so that it is impossible for the inside cover-plate to get adrift. A plate goes on over the oil grooves. Some of the groove walls are made thicker than others to provide for the screws which hold the cover-plate on. The bolts that hold the piston head to the flange of the piston are riveted through and they are all locked with lock-pins and locknuts so that the whole is a unit and cannot come adrift.
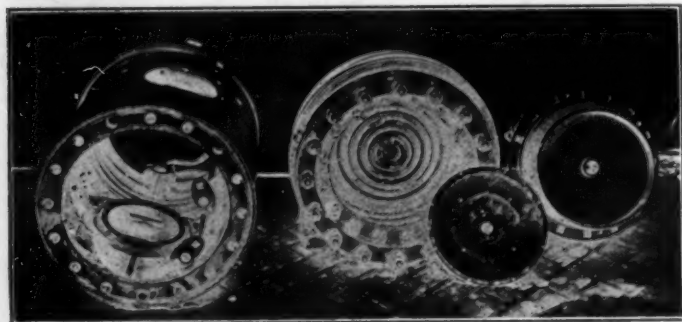
FIG. 6—ONE OF THE DIESEL ENGINE PISTONS TAKEN APART

This design of piston is one of the important departures from former practice. To my mind, it is the most interesting. The cooling-oil pipes are shown which carry the oil in at the periphery and out at the center. The Germans apparently were experimenting more or less with this type of piston for we discovered that the pistons in the engines of the submarine U-140 were slightly different from those of the U-127, although the engine was exactly the same to all appearances. The pistons described were taken from the engine of the U-127 and are apparently of later design.

Another interesting feature about the piston is that on the former engines the pistons were straight from the bottom of the working rings to the bottom of the piston. On this type of piston we found that the skirt was relieved all the way down for a space about 6 in. wide and parallel to the wrist-pin ends. The diameter of the piston is 21 in.

Fig. 7 shows the construction of the connecting-rod and the wrist-pin bearings which is the same throughout all the engines that have cooled pistons. It shows how they provide additional bearing area for the wrist-pin bearings which are subjected to much heat and heavy
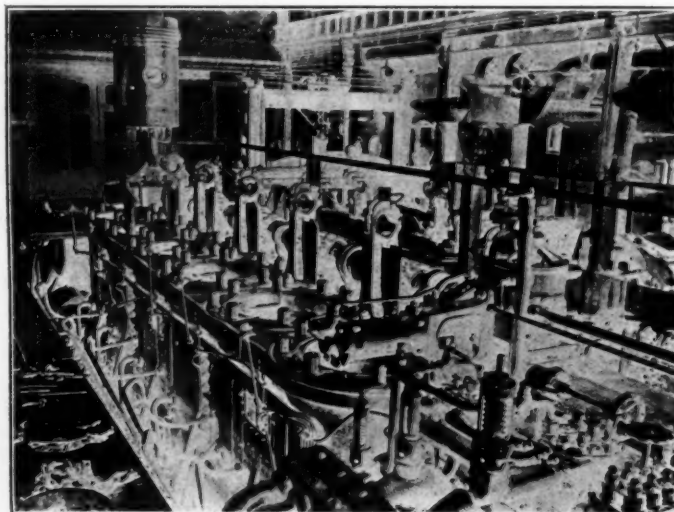

FIG. 7—THE CONSTRUCTION OF THE CONNECTING-ROD AND THE WRIST-PIN BEARINGS WHICH IS THE SAME FOR ALL ENGINES HAVING COOLED PISTONS

pressure. The Germans apparently had no trouble with these bearings for we have had cases where the piston and the cylinder wall have actually scored because of the dirt, and the wrist-pin bearing has not been affected in the slightest degree. A steel forging or casting, I do not know which, goes through the eye of the connecting-rod. It is made in two halves. The upper half of the wrist-pin bearing is shown partly taken out. The lower half has lips or projections to hold the shell in place. The upper half has one small lip and is slipped in last. The wrist-pin bearing is made the extreme width that can be obtained from the inside of the piston; almost double the width of the eye of the connecting-rod is obtained. Naturally, the wrist-pin pressures are very much reduced in this way. The bearing metal, instead of being a bronze bushing, is of comparatively thin babbit metal. They have a fitted distance-piece, measured by micrometers, between the upper half of the bearing and the eye of the connecting-rod. The connecting-rod is drilled out to make it light and when oil is forced to the wrist-pin, this big hole or cavity fills with oil; the inertia of this

oil column tends to pull the oil from the wrist-pin and run that part dry. Instead of putting in a check-valve at the foot of the connecting-rod to prevent this, they have put in a pipe with a screw plate and screwed the pipe into the wrist-pin bearing. The connecting-rod is not filled up with oil and they do not have the difficulty that we sometimes encounter. It is a very simple scheme and there is nothing to go wrong. Another interesting feature in this engine is that the after bearing is of a larger size than the other main bearings of the engine. This bearing is 12.375 in. in diameter; the other bearings are 11.223 in. in diameter. This is done to provide support for the clutch.

Maneuvering Gear

Fig. 8 shows an engine having the same maneuvering gear as the 1200-hp. engine; it has the same handwheel for operating the valve gear. This wheel works through a series of bellcranks and levers and raises the valves clear of the camshaft; the camshaft moves sufficiently to bring another set of cams in line and, to complete the operation, the valve gear is lowered on the new set of cams. On the 1200-hp. engine this was done manually and, while it could be operated readily by the average man, it was a hard task to do this several times per minute in answering the engine room signals. On the 1750-hp. engine this reversing gear can be operated in this way, but it is really all that one very strong man can do; so, in addition to the manually operated gear, a gear is installed which operates by air and also by oil. It is a small box that has four valves in it and by turning a small handwheel in one direction the proper valves are depressed admitting air to a ram. There is an inter-
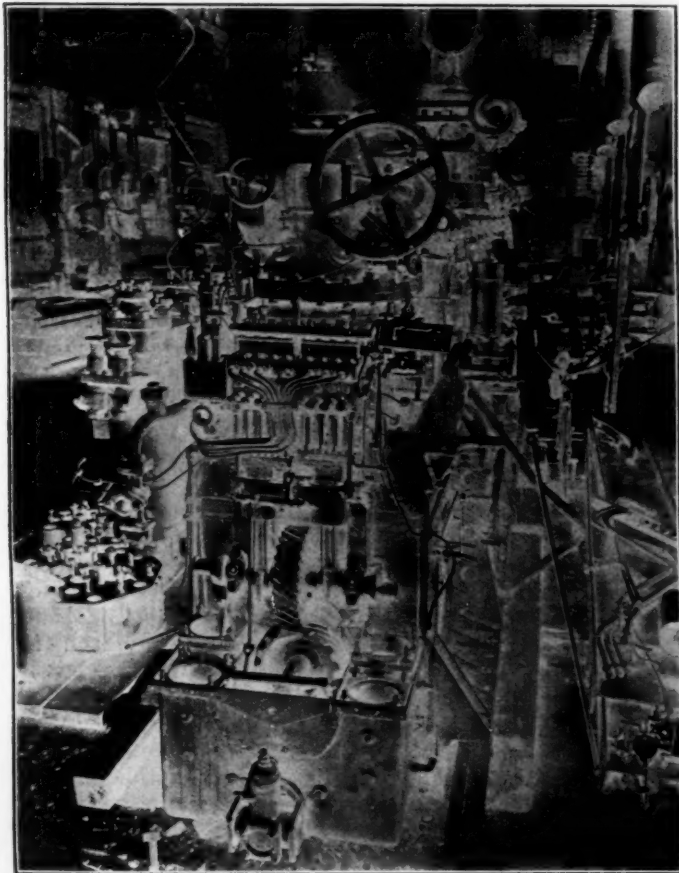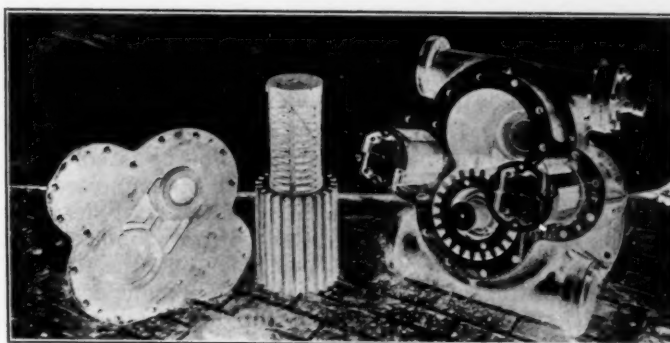

Fig. 9—The Oil Pump Disassembled into Its Various Parts

locking device on the front of the engine so that when the power-operated maneuvering gear is used the hand gear is thrown out. It is interlocked. When this handwheel is turned, the ram goes over in about 2 sec. and the engine is then ready to operate in the other direction. In case the air pressure fails, there is a small oil-pump provided and the ram can be pumped over with oil pressure. The operating gear shown had not been used in two years and we tried it today to see if it would work, as it is was the only thing on the engine that we did not take apart. We found that it operated very satisfactorily, as if it were put together only yesterday. Another interesting feature on this type of engine, which is simple but, apparently very necessary, is a stop valve on the circulating water supply which is operated by the starting levers of the main engine. It is a sluice valve in the header which supplies water for the working cylinder jackets. It is arranged so that when the operating levers are brought to the stop position the water is cut off from the working cylinders, and it is impossible to supply water to them until the engine is started again. From reading a confidential German instruction pamphlet, I noticed that they lay stress on the fact that cold water must not be put into the engine when it is shut down. The water must be turned off the minute the engine stops. But with this engine, even when using independent electric auxiliaries, it is impossible to damage the engine by pumping cold water into it after the gear has been brought to the stop position. That is a refinement and I suppose it is very necessary. I am also of the opinion that this may have something to do with the air-starting of the engine. In other words, it is not possible to put water on the working cylinders until after the engine has started firing. Consequently, when starting with air, the cylinders are not being cooled with cold water.

One other point in the operating gear that does not appear in the older engines is interesting. There are three indicators on the dial of the operating gear, marked *Voraus*, *Tachstellung*, and *Zurick*. The *Voraus* and *Zurick* mean ahead and astern, and *Tachstellung* means diving position. I have been trying to discover a real reason for this third setting, and so far as I can determine, the diving position means the position in which the engine control is placed when the boat dives. It is just the same as the neutral position of the engine, midway between ahead and astern. I think it is one of the refinements that was developed during the war. In case a submarine comes to the surface, the commanding officer is able to maneuver the ship to the best possible advantage. It might also be used in an emergency case, to avoid ramming. If the commanding officer had the controls in the *Tachstellung* position, he would then be

Fig. 8—The Maneuvering Gear of the 1750-Hp. Engine Which Is Typical of All the German Submarine Engines

in the best possible maneuvering position for any emergency that might arise.

Fig. 9 shows the oil-pump. One of the great troubles we have had in our own service is to build a good lubricating oil-pump. I do not necessarily mean a pump that never breaks down, but sometimes oil-pumps make too much noise. This pump is the same kind that is used on all the German engines. It is very simple and consists of two gears, one of which is fitted with a cylinder with grooves cut in it. So far as I can make out, the idea is that in an ordinary gear pump a certain amount of oil is trapped between the teeth after the oil has been discharged, creating a tremendous pressure which naturally makes it pound. The pump shown is designed so that, when the teeth are in a certain position after the oil has been delivered and a certain amount of oil has been trapped, the holes come into position and the oil passes by through the groove. This pump is very smooth running and is almost noiseless. I took one apart on a 1200-hp. engine which had been operating for 25,000 miles, but the original toolmarks were still on it and all we did was to put it together again. It is apparently a very satisfactory design of pump and very efficient.

Fig. 10 shows the main engine clutch on a German submarine. It is necessary to have a clutch between the main engines and the electric motors so that when
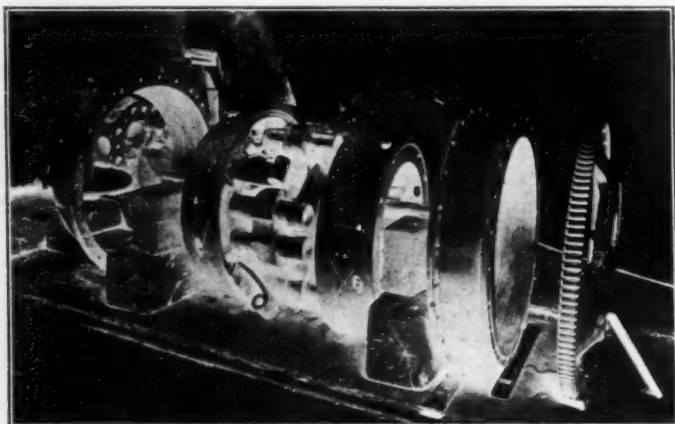
FIG. 10—THE MAIN CLUTCH OF THE DIESEL SUBMARINE ENGINE

the boat dives the engines can be disconnected. This clutch is typical of the German design and is very simple. It consists of two truncated cones. The cones slide on a spider, operated by springs. There is a sleeve on the end, with bellcranks to force the truncated cones in and out against the outside casing. The travel is very small, only ½ in. The angle of the cones is 28 deg. The cones are made of cast iron and the outer rings are steel. They are forced in and out by means of a pneumatic piston which is controlled by a small valve. This control enables extremely rapid engagement and withdrawal of the clutch.

RELIABILITY

I have confirmed my opinion that the German submarine engine is extremely reliable. Some thorough tests were made on a 1200-hp. engine without any trouble or breakage. This was an old engine which had been horribly abused. It was overhauled, put in operation, and ran without much trouble. A former German submarine, the U-111, was operating last winter with some of our submarines. It had a green crew and none of them knew anything about the engine. The vessel operated all

winter until it came to the League Island Navy Yard for docking and painting preparatory to some speed trials. I talked with the commanding officer, and told him his engine was not adjusted properly, but in spite of this it was running very well and was misleading on account of such satisfactory operation. I persuaded him to allow the gang of men I had used on previous engine tests to tune the engine up for him. It was found that everything possible on the engine was wrong; it was all out of adjustment. The gang cleaned the engine parts, set the valves, ground them in tight and set the parts according to the data we had collected on this 1200-hp. engine on test. The vessel went out burning up its fuel perfectly. She developed over 17 knots, while on the previous trial she could not make 14 knots. This demonstrates that the German submarine engine is reliable and can run even if the personnel are not highly trained. That is a condition we must meet in submarine service.

The submarine Diesel engine is not an ordinary Diesel engine, mainly because the requirements are so exacting. The submarine demands everything of an engine that is difficult to get. The space and the weight are limited; the service and treatment are very severe. The requirements of a submarine Diesel engine might be considered as a quest of the absolute. It must be entirely free from imperfections both in design and workmanship. The Germans spared nothing on the submarine campaign to win the war, and I think the results have shown themselves in the development of the M. A. N. four-cycle engine. Many people who have seen it state that it is complicated. I feel now, since I am more or less familiar with it, that such statements are made by people who have not given careful thought to what the engine is supposed to do. To bring this point out more clearly, I will take for example, a little device on the forward end of the engine which is used to stop it from the conning tower or the bridge of the vessel. We had a similar device on our gasoline boats in the early days. This consisted of a little switch in the conning tower by which the ignition-system circuit on the gasoline engine could be broken in case of emergency. The same idea was proposed for the Diesel engine, but we had a better interior communication signal on the later boats and we did not see any need for it; submarine officers stated that it simply made the engine more complicated. But if we stop and think for a moment, it becomes very apparent that with a larger-sized boat having larger compartments and a big induction valve supplying air to the engine room, when crash diving it is necessary to stop the engines from the bridge to be sure that they are stopped before the main induction valve of the boat is closed. What would happen if the man in the engine room was slow in obeying the signal? Suppose he did not get the signal or was not at his post at the time the signal came through and the induction valve was closed. A vacuum would be produced inside the hull which might kill everybody aboard and cause the loss of the boat. One may not be able to understand at once the reason for everything on a German submarine Diesel engine, but if careful study is made, a very good reason will be found for all of the so-called complications on these engines.

One of the controlling factors in the design of this German engine is the steel castings. I think this is true not only of the German Diesel engine but also of the motorboat engine. The Germans have investigated steel casting to the point where making steel castings is an ordinary, every-day job. I think that has much to do with the success of the German engine for they have

made beautiful steel castings. In this country we have found it difficult to get the steel castings made properly, but after many efforts, we are now making a steel casting for the 1200-hp. engine in the League Island Navy Yard with electric furnaces. We employ a 3-ton electric furnace and have done some experimenting which indicates that the trick is in the coring. The steel is poured into the mold and the minute that the metal has set the mold is broken down to get the casting out. The cores are destroyed so that the casting cannot shrink on a stiff hard core. In some of the difficult castings the core is made so that it will crush and, so far, the results have been satisfactory. It is a job that the steel manufacturers of the United States did not want to attempt. But it was felt in the Submarine Service that it was necessary to learn how to make good steel castings. It must be borne in mind that the German engine is a good type, and the information to the world is three years old. It is not only the United States that has this steel casting information, all the other nations have it. The Germans pour steel like we pour brass and make no fuss over it. We do not want to be satisfied with copying; we must lead.

OILS FOR POWERPLANTS

TAKE a wine glass, dip your finger in water and as you rub it over the edge of the glass notice that the friction is pronounced; now wipe the finger dry and dip it in glycerin and again rub the glass, the friction is about the same. Dip the finger in lubricating oil and rub the glass. You find that the friction is almost imperceptible, which demonstrates that while glycerin has a viscosity far greater than the oil, its lubricating quality is lacking, because the surface tension of either water or glycerin is not strong enough to form a substantial film, even under very light loads, for they are both lacking in capillarity and in molecular attraction. For this reason many very viscous liquids fail to form a good lubricating film.

The static friction of solid surfaces when lubricated with lard and sperm oils proves that the lard oil gives the lowest coefficient and therefore must form the thickest film. Experience teaches that when the superfluous oil has drained away the combined capillary and molecular attraction comes to the aid of the viscosity and increases the tensile strength which tends to prevent rupture. Molecular and capillary attraction are possessed to a greater extent by mineral oils when properly refined, than by either animal or vegetable oils, but mineral oils are deficient in oiliness and will not keep the static friction as low as animal or vegetable oils will.

At 500 r.p.m. or more, under normal loads, and with bath lubrication, lard oil will sustain a film only 0.005 in. thick, whereas a pure mineral oil of the proper viscosity will sustain a film about 0.007 in. thick; which proves that for all ordinary machine bearings running under normal conditions, a mineral oil of the proper viscosity is a better lubricant by two-fifths than one of the best-known fixed oils. This has led to the blending and compounding of mineral oils. Blended oils are a mixture of mineral oil and fixed oils in proportions that will thoroughly neutralize; compounded oils are a mixture of mineral oil with metallic soaps of different kinds for the purpose of increasing the viscosity; experiment alone can demonstrate the value of the mixture.

Solid lubricants such as mica, graphite and soapstone have great carrying power at low speeds, but their value depends on the nature of the surfaces. Graphite gives the best results when used on cast-iron surfaces, which are naturally very porous and hold the graphite, but the frictional loss and wear are great. Solid lubricants mixed with animal fats, greases, vaseline or rosin oil are suitable for low speeds and heavy loads, as they give a low coefficient and do not waste away rapidly by evaporation or run off the bearings. Greases compounded from animal and vegetable fats, or mineral oils emulsified with water soap and alkali enough to neutralize them, are good lubricants for slow-moving bearings with excessive loads, provided the oils do not contain too much water and are not adulterated with foreign substances; the oil should not run down and leave the soap, which is likely to occur in poorly made greases.

LUBRICATING OIL FOR LOW SPEEDS AND HEAVY LOADS

In selecting an oil for low speeds and heavy loads, viscosity is the first guide, and next is oiliness. At speeds of 100 ft. per min., with proper application, the oil forms a fairly thick film, and when the load does not exceed 250 lb. per sq. in. the formation of the film and the friction are wholly due to the viscosity; but at heavy loads the bearing surfaces are brought into contact at a point on one side of the bearing and the lubricant should possess oiliness to a greater degree to prevent seizing. In cases of flat surfaces, such as the guide on reciprocating engines, the viscosity is not so important as the oiliness; at loads of 75 lb. per sq. in. a blended lubricant is best.

For motors, generators, turbines and the crankcase type of high-speed engines, best results are had by using a straight mineral oil of the proper viscosity. For motors and generators with bath-ring oiling devices best results are obtained by using a pure mineral oil of a viscosity of from 120 to 198 Saybolt sec. according to the speed and load. Turbines having either forced or circulating lubrication should have a light oil for two reasons: first, because the lighter oils maintain their viscosity better at the relatively high temperatures, and, second, on account of the high speeds. It must also be an oil that will not emulsify and one that will readily separate from water, as there is leakage of steam in most turbines. The viscosity should not be less than 98, nor more than 120 at 100 deg. fahr.

For steam-cylinder lubrication there are four conditions in modern practice that form a guide in selecting a proper oil; namely, steam supersaturated, saturated, dry and superheated. For a supersaturated condition the oil should be heavily blended with pure tallow to give good results; for a saturated condition a light blend of tallow and blown rape will give good results; for dry steam about 6 per cent blown rape gives good results, but for superheated steam one must have a pure steam-refined mineral oil; otherwise the intense heat will burn off the animal and vegetable oil, release the acids they contain and pit the cylinder walls.—C. B. Whitman in *Power*.

EVAPORATION OF CRUDE OIL

THE rate at which crude oil of a given quality and under given temperature conditions will evaporate depends chiefly on the way it is handled. The ordinary method is to pump the oil from the well, force it through a pipe-line gathering system, and then into a tank by overshot connections. In this tank, called a flow tank, any free water is separated by gravity; then the oil is led by another pipe to the lease storage tank. The latter is also filled by overshot connections which permit the oil to fall 8 to 16 ft. and splash into the tank, causing spray. After standing in this tank perhaps 2 to 10 days, the oil is run by the pipe-line company, by pumps and pipe-lines, to the large steel storage-tanks. These have bottom connections and nearly gas-tight roofs. The oil is run from here to large tank farms or directly to the refinery by pipe-lines or tank-cars.

Each of these steps constitutes a different class as regards rate of evaporation. These classes may be divided as follows:

(1) Filling a tank by overshot connections
(2) Filling a tank by bottom connections
(3) Storage in small unprotected tanks on the lease
(4) Storage in small tanks on the lease which have some protection such as shading or an air-tight jacket
(5) Storage in 37,000 or 55,000-bbl. steel tanks which have so-called gas-tight roofs.

Filling the tank by overshot connections is the cause of the most rapid loss. The amount of this loss depends upon several variables, such as the height from which the oil falls, the velocity and size of the stream and the size of the tank as compared with the time required to fill it. Several tests were made which show that the loss in 24 hr. from such conditions ranges from 1 to 2.5 per cent of the original volume in the summer time.

Evaporation during storage on the lease in unprotected tanks shows a high rate. Data obtained from some of the largest independent producing companies in the Mid-Continent field show that the average storage period is five days. In that time oil stored in an unprotected 250-bbl. steel tank will lose from 2.8 to 3.1 per cent by volume; oil stored in a 500-bbl. unprotected steel tank, about 2 per cent; a 1600-bbl. wooden tank, which is protected by a house that acts both as a shade and wind-break, will lose about 1.1 per cent. The above figures are for summer conditions, but tests covering this phase of the subject were run for summer, autumn and winter. Even when the temperature of the oil is low, the loss from evaporation is worthy of consideration. During five days a 250-bbl. tank will, at the average summer temperature of 78 deg. fahr., lose 2.8 per cent by volume, and at the average winter temperature of 38 deg. fahr. 1.7 per cent. Although the temperature has been reduced from an average of 78 deg. fahr. to 38 deg. fahr. and the oil is nearly at the freezing point of water, the loss is still more than one-half of what it would be at the summer temperature. In addition to the tests on housed wooden tanks, comparative tests were made with other types of protected tank. A 500-bbl. steel tank was fitted with a jacket having a 3-in. clearance. Tests of this tank show that approximately two-thirds of the evaporation loss was eliminated by jacketing. A comparison of the cost of the protection with the value of the crude oil saved shows that the jacket would pay for itself in three to four months.

Filling a large tank with bottom connections will cause a rate of evaporation, for a five-day period, which is second only to that from filling a tank with overshot connections, because the oil in the tank is agitated by the inflowing stream and by the ebullition of gas and air, which have been entrapped in the pipe-line. Data were kept on semi-monthly losses in 80 steel tanks having capacities of 37,000 and 55,000 bbl. from which the average evaporation loss was computed. The oil under consideration was that produced near Ranger, Tex., and had a gravity of 40 deg. Baumé. Oil of various ages was tested and the results show that oil stored in such a tank will in the first year lose 3 per cent of its original volume, and in the second year 2.1 per cent. In considering the evaporation losses of crude oil, one must remember that the portion which escapes is gasoline, and moreover the lighter, most valuable part of the gasoline. The value of the fraction is more than three times the value of an equal volume of crude. If a 2-per cent volume loss is shown at any point, this means that 6.5 per cent of the value of the crude has disappeared.

It is possible to eliminate from two-thirds to four-fifths of the evaporation loss by protecting the oil from free contact with air. In a few years crude oil will probably not be exposed to free contact with the air in any case, except when necessary for gaging or sampling.—U. S. Bureau of Mines.

WATER-POWER DEVELOPMENT

COAL alone represents more than one-third of the country's total freight, and much of it has to be carried very long distances to supply the requirements of our widely scattered population. The steam railroads consume more than 160,000,000 tons of coal annually. Under existing conditions of power generation, moreover, the greater our progress in manufacturing, the greater becomes the burden upon our transportation systems in the way of the haulage of fuel. We cannot find a way out of our present difficulties through a retention of the wasteful system of isolated steam-power production with a shifting of dependence from coal to petroleum.

In 1901, when the Federal legislation was enacted under which most of the water-power development of the country has taken place, there was less than 2,000,000 hp. in use. It is estimated that at the beginning of 1920 the development reached 9,823,540 hp., or one-sixth of the maximum potential resources. The Atlantic States south of New England lead the country in water-power development. Among the individual States New York holds first place, with 981,520 hp. developed; California, with 942,000 hp., is second on the list; and Maine, with 780,000 hp., holds the third place among the States in which the streams are utilized for power.

Generally speaking, more than three-fourths of the potential water-power of New England has already been developed; in the remainder of the country east of the Rockies roughly one-third is developed; and in the Far West about one-sixteenth is in use.

In the Pacific States there has been a remarkable development in the construction of long-distance power lines fed with current from a great number of stations. Through the consolidation of utilities and the interconnection of systems there is now in California, from a practical operating point of view, but one vast system, with lines reaching from the Oregon border to Mexico, over a distance of 800 miles, with 75 hydro-electric and 47 steam plants and 7200 miles of high-tension transmission lines. The installed capacity of the system is 785,000 kw. and approximately 600,000 consumers are served. California uses more electric power on farms than all the remainder of the United States. The summer wheat in at least a dozen counties was threshed by electricity. One company supplies power to 60 towns and 500 farms. —Sea Power.

METAL FATIGUE UNDER REPEATED STRESSES[1]

THE failure of machine parts under repeated stress has come to be commonly spoken of as due to "fatigue" of the material. The cause of such failure used to be thought to be the "crystallization" of the metal, but the phenomenon is one of a breaking up of crystals rather than of their formation. The development of the internal-combustion engine, the steam turbine, the automobile and the airplane has made this problem of fatigue of materials of increasingly marked moment during recent years. The accompanying table gives some idea of the number of repetitions of stress in the normal life of various structural and machine members.

Part of Structure or Machine	Approximate Number of Repetitions of Stress in the Life of the Structure or Machine
Railroad bridge, chord members	2,000,000
Elevated railroad structure, floor beams	40,000,000
Railroad rail, locomotive wheel loads	500,000
Railroad rail, carwheel loads	15,000,000
Airplane engine crankshaft	18,000,000
Car axles	50,000,000
Automobile engine crankshaft	120,000,000
Line-shafting in shops	360,000,000
Steam engine, piston-rods, connecting-rods and crankshafts	1,000,000,000
Steam turbine shafts, bending stresses	15,000,000,000
Steam-turbine blades	250,000,000,000

The first study of fatigue phenomena on a large scale was made in Germany by Wohler, who published his results in 1870. These results may be summarized as follows:

(1) Repeated application of stress to a structural member will finally cause failure not only when the unit stress is less than the static ultimate strength of the material, but even when it is less than the static elastic limit as ordinarily determined

(2) Within certain limits the range of stress, the difference between maximum and minimum stress, rather than the maximum unit stress, determines the number of cycles before rupture

(3) As the maximum unit stress is increased, the range must be decreased in order not to shorten the life of the member

(4) For the same life in the case of complete reversal of a unit stress, the stress should be only one-half or two-thirds of the maximum stress if the variation is from zero to a maximum

A fatigue failure is characterized by the complete absence of elongation or reduction of area at the break. The fracture is sudden and similar to that ordinarily expected only from brittle materials. A rotating beam will crack at right angles to the length of the beam, which is also at right angles to the direction of stress.

Metals, while being subjected to fatigue, have been observed under the microscope, and it has been found that the crystals of which a metal is composed will allow deformation to occur by movement along certain gliding planes within the crystal. These are called "slip lines," or "slip bands." Careful examination of cross-sections cut at right angles to the surfaces on which the slip lines occur has shown that the slipping causes microscopic ridges and depressions of the surface, in the nature of steps. Vertical illumination of such a surface shows the steps as bright surfaces and the inclined surfaces between the steps as dark lines or bands. As the test of the material in fatigue is continued the slip lines become more numerous and also broaden. Finally some of these develop into a crack which spreads to other crystals and thus causes failure. It has been found that the crystals which first develop slip lines are not necessarily the ones in which final failure occurs.

In general, fatigue failure follows a path through the crystal grains themselves rather than along their boundaries, and this is true even though in going from one crystal to another the plane of failure must change its direction, because of the different orientation of the crystals. It appears, therefore, that the primary cause of fatigue failure is localized deformation. This deformation in any particular crystal is very small in amount and apparently even very accurate and sensitive extensometers cannot detect the deterioration which is going on. Because steel is made up of many minute crystals, the structure is not likely to be homogeneous. Furthermore, there are likely to be many microscopic flaws throughout the material. Somewhere, on account of either non-homogeneity or flaws, there will be high local stresses, and at such places the material will be most likely to deteriorate by the repeated action of fatigue stresses. The presence of internal stresses, due to previous heat-treatment or mechanical treatment, would also tend to weaken the material when fatigue stresses of a similar kind are applied later.

MECHANICAL HYSTERESIS LOOP

Tests conducted with apparatus of extreme sensitiveness have shown that the action of materials within the ordinary elastic limit is not perfectly elastic. For instance, when a specimen is first loaded in tension, and then the load is reduced to zero, the return path of the stress-deformation curve does not coincide with the original path, but lies slightly lower, the deformation seeming to lag behind the stress, so that when the stress is zero the deformation of the specimen is not yet back at zero. If now the specimen is loaded in compression, and the load reduced to zero, it is found that a loop has been formed by the stress-deformation curve. This loop is called a mechanical hysteresis loop, from analogy with magnetic hysteresis. The area of this loop represents energy which has been absorbed by the specimen but not given back again. In each cycle of stress, therefore, there is a small amount of work done because of the inelastic action of the material. In careful torsion tests Guest and Lea obtained hysteresis loops for mild steel at unit stresses which were very much below what would ordinarily be called the elastic limit. Such results constitute a further explanation of the possibility of failure of a material when stressed within what has heretofore been looked upon as the elastic limit. This so-called elastic limit may be regarded as of value when discussing static stresses, but it seems evident that it is not an elastic limit for reversed stresses, because the hysteresis loops indicate inelastic action. Bairstow has shown that when a cyclical stress sufficiently below the elastic limit is applied to a specimen, no hysteresis loop is formed at first, the amount of damage done during each cycle of stress being apparently too small to be indicated even by a very delicate extensometer. However, after a few thousand repetitions of the stress the cumulative effect of the repetitions is evidently of such a nature as to make measurable the changes which occur in the specimen and a hysteresis loop appears.

In determining the resistance of metals to fatigue, Wohler used machines which subjected the specimens to direct tension and compression, to repeated bending on a stationary beam, to reversed bending on a rotating cantilever beam, to repeated torsion and to reversed torsion. In the direct stress, repeated bending and torsion tests Wohler used machines in which calibrated springs were employed to measure the load applied to the specimen. This general type of machine is quite common. The rotating-beam type, either cantilever or simple beam, has probably been more extensively used than any other machine. Wohler's machines applied the stresses at rates less than 100 per min. so that many weeks of testing were required to stress a specimen

as many as 10,000,000 times. In later types of machine attempts have been made to increase the speed of the machines, and speeds up to 2000 r.p.m. have been used successfully. A machine of this kind running 24 hr. per day will give results fairly rapidly.

Various other types of testing machines have been employed by experimenters. In some the stress is produced in the specimen by the acceleration effects of reciprocating masses, in others the pull is applied by an electromagnet, and in still others the reversed bending which is produced occurs in only one plane. Machines for producing reversed bending on a cantilever beam have been used by Arnold and others. These machines stress the materials beyond their yield points so as to produce failure after only a few hundreds or thousands of cycles of stress. In such a test the stress to which a specimen is subjected is not known, and it is therefore difficult to interpret the results. Thus far it has not been shown what relation exists between this short-time test and the test which stresses materials only within their elastic limits. In the ordinary fatigue test the machine is set to produce a certain stress in the specimen, and the test is continued until failure occurs; the number of cycles of stress before failure being recorded by a suitable counter.

Attempts have been made to show that a relation exists between the endurance limit and the elastic limit as determined from a static tensile test. These attempts have not been satisfactory, and this is to be expected, since the endurance limit which was used was itself indefinite. Furthermore, the elastic limit is also an indefinite quantity, and depends to a considerable extent upon the sensitiveness and accuracy of the instruments employed in determining it and upon the accuracy used in plotting the results. It has been shown that a material having a higher elastic limit than another one is not necessarily better in withstanding the destructive effect of repeated stresses for a long time.

There is at present no short-time test which has been proved to be a reliable criterion of fatigue strength. If such a test could be developed it would of course be of the greatest commercial importance.

TESTS BEING CONDUCTED

In the fall of 1919 there was started at the University of Illinois an investigation of the fatigue of metals under the joint auspices of the National Research Council, the Engineering Foundation and University of Illinois Engineering Experiment Station. This investigation is at present organized and financed to be carried on until the fall of 1921. In planning this investigation it was decided by the advisory committee of the National Research Council that it should be the object of the investigation to make a series of fatigue tests of seven or eight typical steels accompanied by very careful static tests and impact tests, and in connection with these tests various special ones including magnetic tests.

The testing machine chosen for the repeated stress tests is of the rotating-beam type. This gives reversals of a very definitely known bending moment, and there is a considerable portion of the specimen under constant bending moment. The specimen is a straight rod slightly reduced in section over the middle portion of its length.

By past investigators there has been obtained a considerable amount of data on the fatigue failure of metals, but the committee felt that there was need for a comprehensive series of tests on metal whose history was thoroughly known, correlated with very careful static tests of the same material. It is planned for each kind of steel, to run not less than six tests to 100,000,000 repetitions of stress, and to obtain 18 to 24 points on a diagram of fiber stress plotted against numbers of repetitions of stress necessary to cause failure.

INTERNATIONAL CIVIL AVIATION ORGANIZATION

THE wonderful progress made in aeronautics during the war was due partly to the unlimited financial means placed at the disposal of research workers, designers and aircraft manufacturers, but principally to the spirit of mutual cooperation prevailing at that time between the nations entering the two opposite belligerent groups which led to the adoption by all of certain types of machine and the abandonment of others, the establishment of rules and regulations common to all and the cooperative study of the various theoretical and practical problems which to a greater or less extent have some effect on the design, construction and operation of the airplane.

Under the present peace-time conditions we find that the airplane, as it is, is adequate to the requirements of civil aviation. Any attempt to establish civil aviation with a view of serving the needs of one single country only, with the exception perhaps of large countries such as the United States and Russia, cannot be a successful business enterprise because the airplane at the present stage of development cannot compete with the railroad over short distances, especially the present all-wood airplanes. We need cooperation on the part of the various governments in passing laws regulating air navigation, in granting facilities for the establishment of airdromes where needed in utilizing commercial aviation for carrying mail, etc. We need cooperation on the part of research organizations in solving the many problems involved in flight. We need cooperation on the part of aircraft manufacturers for producing efficient types of commercial machine such as they have not yet produced.

All this can be accomplished in a comparatively short time, but if commercial aviation is to be established along international lines and be a good business enterprise, we must not leave it to each nation to work out the problem from within. What is needed is a powerful organization that will approach the problem from an international point of view, establish and operate aerial lines of communication, tying together the most important commercial centers of the world, take the initiative in framing the legislation needed for governing the navigation of the air and be able to outline a program for the aircraft manufacturers of the United States and Europe to work on. This could be the structure, the foundation of commercial aviation that would start operating along international lines and be the pattern on which commercial aviation could be established in each country for serving the particular needs of the various countries in the world and operating in connection with the international air routes.

Three distinct branches of activity are required in such an organization. One branch needs to be concerned with real estate problems such as buying, leasing or otherwise obtaining the necessary grounds at points of arrival and departure of the aerial expresses, construction of hangars, warehouses, workshops, terminal stations, office buildings, subsidiary railroad lines, etc. A second branch will have to deal with the production of airplanes, engines and equipment. The third branch will have to take care of the operation of the aerial lines. Each of these three could be organized as a separate corporation, all three being controlled by the same financial group. Such an arrangement would offer the advantage of possessing the required flexibility for the successful operation of the whole organization.—William Knight in *Aerial Age Weekly.*

Discussion of Papers at the Annual Meeting

THE discussion of the papers presented at the recent Annual Meeting of the Society included written contributions submitted by members who were unable to be present and the remarks made at the meeting. In every case an effort has been made to have the authors of the several papers reply to the discussion, both oral and written, and these comments, where received, are included in the discussions. For the convenience of the members, a brief abstract of each paper precedes the discussion, with a reference to the issue of THE JOURNAL in which the paper appeared, for the convenience of members who desire to refer to the complete text as originally printed and the illustrations which appeared in connection therewith.

AERONAUTIC PROPELLER DESIGN

BY F. W. CALDWELL

IT is of course impossible to consider propeller design very much in detail in a paper of this nature. It can be said, however, that the airfoil theory, in connection with the inflow theory, has given very good results and proved exceedingly valuable for the aerodynamic design of propellers. Both theories, however, in the present state of knowledge, must be applied with a number of empirical factors.

Propeller-design theories and the subject of aerodynamics are discussed mathematically, as well as the elements governing the best propeller diameter for obtaining the highest thrust. Consideration is given in detail to steel, adjustable-pitch and reversible propellers as well as to those made of laminated construction consisting of sheets of paper fabric impregnated with bakelite as a binder. The mathematical considerations that apply to propellers when reversed in flight, the time and distance required to stop when landing and propeller stresses are enumerated and commented upon.

The tendency of propeller design is discussed and the methods of propeller testing are described. The paper is copiously illustrated. [Printed in this issue of THE JOURNAL]

THE DISCUSSION

PROF. E. P. WARNER:—Mr. Caldwell's paper is of peculiar interest at present because, after having been in a state of constant change and improvement for a number of years, propeller design seems now to be arriving at something like finality. It appears probable, from the work that has been done at Dayton, elsewhere in this country and abroad, that it will be possible within a short time to predict accurately the characteristics of a propeller from nothing more than a knowledge of the sections employed in the making up of that propeller.

As to what is being done abroad, in addition to experiments with the thrust-meter that they are working with, the British are obtaining the pressure distribution on a propeller in flight as well as in the wind-tunnel, to provide data for the application of the new-type propeller-theory to design. The Royal Aircraft Establishment is actually obtaining in flight now the pressure on 105 points of the propeller, and they can build up the thrust and the torque from these pressure plottings. In the matter of strength testing that Mr. Caldwell mentions, the European method is different. The most striking difference to me, after seeing what they are doing in England, is that they attempt to catch the propeller without serious injury, in going against boards or concrete. For that purpose the propeller is surrounded, in both British and German laboratories, with wire fence of an exceptionally springy weave. It has a springy mesh with the idea that, when a part of a blade lets go, it will strike the wire and rebound, be less injured and be easier to examine afterward than if it goes against a concrete wall. They seem to have good success, although they do not test to destruction, as a rule. Usually, they run the propeller up to 25 per cent overload and, if it stands up, do not attempt to break it.

They are working in England with a propeller made up of an aluminum frame having sheet aluminum screwed on both sides as a cover. That was not tried in flight last summer but tests on it were reported to show very good results. It gives a better form than most of the steel propellers that they have had. It is a promising rival to the steel propeller, if wood is finally abandoned on account of its poor resistance to climatic conditions and its poor durability.

THE DESIGN REQUIREMENTS OF COMMERCIAL AVIATION

BY GROVER C. LOENING

AFTER rehearsing instances in the progress of aviation in which an unexpected realization of some radical departure from previous practice led to unwarranted hopes that various aviation problems had been solved completely, the author states six specific false leads or misdirections of aviation development and comments upon them at some length. He then discusses what the influence of war aviation has been.

Passing next to future needs, four specific points of questionable development are enumerated and commented upon, followed by a similar consideration of desirable developments which are grouped likewise under four specific headings, numerous illustrations of present-day airplanes being given including some constructional details of the Junker-type and of metal-covered wings.

In conclusion, the author indicates that it is possible, in a resume of design characteristics and requirements for commercial aviation, to place many developments in their proper category by emphasizing that all-metal construction is a secondary need, a gradual development in itself already resulting in partial metal construction and that, in structural features, what is needed is great simplicity and refinement in the reduction of the number of parts and fittings, whereas in designing and installing the engine, present lines must be followed a little more consistently and patiently to obtain that element of reliability which is more important than any other element in connection with airplane construction. [Printed in the February, 1921, issue of THE JOURNAL]

THE DISCUSSION

R. H. UPSON:—Some evidence on the subject of small single-engined versus large multi-engined airplanes will be interesting. Having made a trip across the English Channel last spring in one of the single-engined planes, and not having the time or opportunity to try the Handley-Page machine in comparison, the best substitute I could get, which I think was really a better means of comparison, was to talk with several people who had tried both and find out the general public sentiment in regard to this subject. I found, without any exception, that the small planes were preferred by those among the general traveling public who had had any opportunity to judge. In the first place, they were faster. That is not necessarily a factor which has to do solely with small machines. They also seemed to be steadier and better liked by people in general.

Regarding the general subject of design, after all, there is no effective substitute for good engineering, which simply means suitability of construction all the way through for the purpose intended.

C. D. HANSCOM:—I was much interested to hear that the Post Office Department found that both engines frequently stopped at once. We have not heard of any instance where that has happened to our planes. The Martin company is trying to keep a service record of each of its planes. If there have been cases where both engines failed, on one of our planes, our records are incomplete.

G. C. LOENING:—I have no information regarding specific instances.

MAJOR L. B. LENT:—I know of no instance where both engines have stopped at once, although that may have occurred. As Mr. Loening has pointed out, the trouble has been due largely to factors outside of the engine itself. The structure of the present engines is entirely satisfactory. We have been using Liberty engines largely. There is still a long way to go, however, in improving fuel systems; most of our failures have occurred from that source. The engines of our twin-engined machines have stopped at various times.

E. R. ARMSTRONG:—We are losing sight of the main thing, which is the carrying of a load a given distance reliably and continuously. It is not a question of two engines or of six engines. I could start a discussion among these engine men as to whether the old single-cylinder Cadillac was as good as the 12-cylinder Packard

engine. It is a matter of reliability. I believe that Mr. Loening will agree that if we eliminate things which these statistics show have caused the delay, the twin-engine installation may be just as good as one having four engines. The fact that calls to my attention the suitability of one over the other is the useful load per horsepower. I think that has not been emphasized enough among engineers generally and among people dealing with commercial aeronautics. The usual load is 6 lb. per hp. That is construed as the load of fuel or passengers or whatever else. If, in turn, we interpret this in flight-hours on a basis of 0.5 lb. of fuel per hp.-hr., it means a 12-hr. flight or a 6-hr. flight and a balance of 3 lb. per hp. available for useful load in the form of profit-earning merchandise.

The construction that will give the largest useful load per horsepower is the construction that ought to be worked for, whether it is two, four or six engines. In addition, there is no object in carrying a useful load unless it is carried continuously and reliably. The chief reason for the failure of commercial aeronautics, where it has failed, referring now to 'cross-Channel work particularly and to the mail planes, has been the cost per ton-mile and lack of continuity of flight. We can never hope to carry mail, passengers, express or freight on a commercial basis unless the speed of the airplane is taken into account in reliability. The attention of all automotive engineers should be directed to the design that will produce an airplane that will fly continuously and most economically.

H. J. MARX:—In connection with Mr. Loening's comments on retractable chassis, I wish to add a few notes on some experience I have had recently in adapting such a design to the VE-7 machine for the Navy Department. One of the points I wish to bring out is the fact that I agree with Mr. Loening on a number of matters at present, although I feel that there will be a number of changes in the future that will give a very different and more promising aspect to the entire situation.

First, in designing a retractable chassis, if we keep the same wheel track, we have about 5 ft. between wheel centers. If we retain the same centers in retracting the chassis, we must push it up through the wings or change the angle of the axle from the normal. This causes a number of complications in the actual design of the wings, and also in the matter of streamlining the wings so that the chassis struts are concealed. This means that we lose part of the lift values for that particular portion of the wing section and add slightly more resistance. Another handicap is that the struts must be very strongly constructed, requiring considerable reinforcement in the design and making it rather difficult and expensive to manufacture.

There is no doubt that for a small machine the retractable chassis does not present sufficient advantages to warrant the expensive and complicated installation. If we consider its adaptation to a large-sized machine, we encounter the increased requirements of shock-absorption. If we use the old type of shock-absorber, there is a large mass that we must streamline, which adds considerably more to the resistance. That has been partly overcome by Mr. Martin's design of a shock-absorbing wheel. This is constructed with the entire shock-absorbing device inside of the actual diameter and width of the tire. Adapting this type of wheel to a heavy plane would mean considerable experimental development in that wheel at present, as present design is limited to the lighter type. The retractable chassis also presents serious difficulties

so far as the retracting mechanism is concerned, increasing the weight of the machine above that which the normal chassis requires. It is very difficult to adapt the retractable chassis to a machine that has already been designed and constructed. Those difficulties can be overcome entirely in connection with a new machine, by designing the machine and the chassis at the same time. There are, however, large possibilities for further development of that design beyond what has been attempted so far in the field.

ADRIAN VAN MUFFLING:—Mr. Loening hit the nail on the head when he said that the present-day aviation engine has too many refinements. What we want to do is to develop a strong, rugged six-cylinder engine that is something like a Ford engine, which would be just as reliable and could be adapted on the same principle of standardization as the Ford engine is adapted to the Ford chassis. There is no doubt that the present-day aeronautic engines are built too much like Swiss watches. If anything goes wrong with them it is very difficult to repair them and in most cases one cannot get the needed parts within a reasonable time. Commercial aviation in this country depends upon the development of a standardized, cheap, low-speed and perhaps fairly heavy engine of great reliability.

E. A. SPERRY:—The efficiency of the aeronautic engine ought not to be omitted. Engines on long flights may easily consume many times their own weight in fuel. Efficiency is very important. As Mr. Loening says, we can use a heavier machine if it be more efficient. I do not agree with Mr. Loening's remark that we must plug along with the present engine. A new day must dawn in engines. The aeronautic engine must be not only reliable, as every one agrees, but far more efficient.

MR. LOENING:—I referred to plugging along the present lines in the direction of greater reliability, by reducing the power of the engines of present weight or adding weight to the light engines.

MR. SPERRY:—We must not neglect the very vital point of fuel consumption and efficiency. If we can get far more power out of the fuel, we can carry much more freight or increase the radius of operation very much or both. Moreover, the more efficient machine will not depend upon export or aviation gasoline, but operate upon a fuel that costs about one-fifth of what aviation gasoline costs. Moreover, each gallon of the cheap fuel oil has 25 per cent more thermal units in it. There are many things to be gained by reaching out for improvement and we must not be content with mere "plugging along." Although it may seem to Mr. Loening that the stabilizer got in the way of progress, yet it has made a substantial contribution in a field where the public has not had access to the record of its achievement, which for military reasons has been kept a secret.

SOME EXPERIMENTS ON THICK WINGS WITH FLAPS

BY C. D. HANSCOM

THE subject of thick wings has been taking on a constantly increasing importance in aeronautical discussions for several years. Since the war, with the urgent necessity for instant production removed, aeronautical engineers have been turning to practical experiments. The paper presents the results of tests made for the Glenn L. Martin Co. in the wind-tunnel of the Massachusetts Institute of Technology in an endeavor to obtain more data on the action of wings with flaps. Both front and rear flaps were employed. Ultimately four base sections were adopted and the new wings developed from them.

The first, and most logical, choice was the USA-27. The second base section was the H-1, a wing designed by the author, the data for which have not heretofore been published. A third base section was the D-1, designed by G. M. Denkinger. The fourth master section was a composite curve which resembled no wing in particular. From these master curves six new wings were developed, the details and modifications of these being discussed and their characteristics described by curves and tables of data presented together with considerable detailed comment thereon. [Published in the March, 1921, issue of THE JOURNAL]

THE DISCUSSION

ADRIAN VAN MUFFLING:—Wings have been developed recently in this country that show an L/D ratio of between 26 and 27. It is interesting also to note that the wing-curve is a mathematical curve.

PROF. E. P. WARNER:—For those who are perhaps not able to keep in touch with what has been done on wings, I emphasize the extreme importance and merit of the tests reported by Mr. Hanscom. The 0.00516 lift coefficient obtained is slightly more than 7 per cent higher than any such coefficient that has ever been found before. The highest previous result was obtained in England; this goes far beyond it and it is a much more practical type of wing. Will Mr. Hanscom tell something about the relative merits of the front and rear flaps and whether he thinks the front flap is worthwhile mechanically? Is it not sufficient to use the rear flap alone and leave the front of the wing set in the most efficient position?

C. D. HANSCOM:—Except for very high speeds, very little gain is to be had by changing the position of the leading edge. For a racing machine, or for a machine intended to reach a maximum speed over twice its minimum speed, I think there is value in the front flap; otherwise, not. Professor Warner, having been in charge of the tests that were run, is familiar with these wings.

R. H. UPSON:—Having had considerable experience in airplane trips, especially in those approaching commercial conditions, with the prevailing bumpiness in hot weather, I have wondered whether it would not be feasible to center particular attention on that aspect of the question in the design of the wings themselves. That is, to attempt not only theoretical efficiency but also smooth driving qualities, by the form of the wing, the introduction of spring flaps or something of that nature.

MR. HANSCOM:—I think that would be exceedingly interesting but, aside from the possibilities of the spring flap, I believe much experimenting would be required to determine a wing curve that would give those qualities. I have not gone into that subject and cannot say offhand

whether a variation of section would have a very marked effect on the bumpiness.

A MEMBER: — What relative advantages would the leading-edge or trailing-edge flaps have?

MR. HANSCOM:—They operate in different ranges. The change in the position of the leading edge benefits a wing at high speeds. At all L/D ratios the rear flap is the controlling one.

E. R. ARMSTRONG:—From a practical point of view, am I correct in my understanding that you are seeking a high-speed wing that will give low-speed landing?

MR. HANSCOM:—Yes; and also a very high-lift wing, to carry great weight with small size.

MR. ARMSTRONG:—I imagine that is secondary. In a practical machine such as the Martin bombing airplane, where the speed is 120 m.p.h., what would be the minimum landing speed provided your theoretical deductions were applied to that machine?

MR. HANSCOM:—The testing of these particular wings was finished only yesterday and I have not had time to make examinations as to the properties of the machine. Unquestionably there would be a considerable increase in the maximum speed. These tests have been going on for some time but the last of them have just occurred. Prior to securing the final results we are not doing any development work from the sections.

MR. ARMSTRONG:—What I had particularly in mind is not the maximum speed but the lowest landing speed.

MR. HANSCOM:—If we set a minimum speed, we get a higher maximum speed. It works either way. On the present type of machine the difference, I think, would be between 10 and 20 m.p.h.; I cannot say definitely before investigating further. That includes the benefit derived from partial internal bracing. The wings are thick enough to permit considerable internal bracing.

CHAIRMAN GLENN L. MARTIN:—I think Mr. Armstrong desires to know how much lower the landing speed would be, if the airplane were as it is now with the exception of additional flaps.

MR. HANSCOM:—If a newer wing were substituted the landing speed would be cut down from about 60 to between 40 and 45 m.p.h.

CHAIRMAN MARTIN:—In other words there would be a decrease of from 25 to 33 per cent.

COMMERCIAL AVIATION IN THE EASTERN HEMISPHERE

BY EDWARD P. WARNER

THIS paper is illuminative and affords an opportunity for better comprehension of the remarkable progress and accomplishment made in Europe along the lines of commercial aviation. Reviewing the present European routes now in regular or partial operation, the author stresses the essentialness of the attitude of the press in general being favorable if commercial aviation is to become wholly successful.

The airship appears most practical for long-distance service, to the author, and he mentions the possibility of towns and cities growing up around "air ports." The cost of airship travel is specified, although it is difficult to figure costs and necessary charges because so few data on the depreciation of equipment are available.

Regarding successful operation, much depends upon the efficiency of the ground personnel and organization. It is present practice to send out to aviation pilots by radio telegraph hourly weather warnings which give the height of the clouds, the degree of fog at ground level and details of visibility.

Following a discussion of the matter of Governmental subsidies, the author describes the different kinds of machines and states many of the advantages and disadvantages of single and multi-engined aircraft, his opinion being that multi-engined machines are necessary, especially for extremely large units.

The main subjects considered thus far include the necessity of securing public confidence in the safety and reliability of the service, insurance, governmental assistance, the Air Convention, the matter of passports and visés, customs airdromes, the status of manufacturers, enclosed cabins, the materials of construction, the desirable number of engines, marine aircraft and the possibility of using transferable packing-cases. The illustrations show a few of the types of airplane most commonly used in transport and "taxi" service. [To be printed in an early issue of THE JOURNAL]

THE DISCUSSION

R. H. UPSON:—In the matter of cooperation between manufacturers and operators, Professor Warner mentioned the fact that there seems to be a growing tendency in Europe to keep the operator distinct from the manufacturer. I do not contravert that statement of fact, but I do not object to the possible inference of its being a model to be followed, especially in starting out along new lines. It is of great importance to have just as close cooperation and connection between manufacturing and operating as is possible. I think it will be found that this has been the rule in Europe. Usually, the builders have supervised the operation very closely at the start, and only after it became standardized to the point where the separation mentioned could be effected has this been done. As an example, consider the German airship Bodensee. It was operated not only by the people who constructed it but between two construction stations. This was considered of very great advantage.

It was my experience that airsickness while crossing the English channel is not due to bad air. We had a window open. The trip was as rough as any I have made by boat, but it was completed much more quickly.

PROF. E. P. WARNER:—As to the airsickness I did not base my statement on personal experience. I did not make the Channel crossing in the air but know a number of people who did and some of them were very sick. In the case of one machine on test, the observer was an officer of the Royal Air Force. The pilot came in perfectly cheerful at the end of 2 or 3 hr. but the observer, shut in the little cabin, was very much knocked out. This indicated that the ventilation was poor.

MR. UPSON:—The man who is piloting the machine is responsible for its safety. He has no time to be sick.

PROFESSOR WARNER:—As a matter of fact, I am sure the airsickness was attributable to the fact that the machine was enclosed. There was perhaps something in the design that caused particularly bad ventilation. In regard to the separation of the builder and the operator, I will grant Mr. Upson's point in the case of the Zeppelin company, which controls several other organizations, and in connection with airships in general. The Zeppelin airship works is at Friederichshafen, and about

2 miles from its Berlin terminus; it produces the four-engined airplanes. It certainly is desirable that there should be the closest cooperation between the builder and the operator, but I believe there should be no connection in the case of airplane companies. If we divorce the two, we will throw on the designer the responsibility of meeting competition in the open market. Let us allow the operating man to run his service, and not get the finances of the two mixed up in trying to make the one support the other.

LADISLAS D'ORCY:—Is it not a fact that the report of the British committee on civil aerial transport stated that commercial aviation could not be operated on a profitable basis except through subsidy in one form or another?

PROFESSOR WARNER:—There is a report, issued during the spring of 1920, from a committee made up of ten very distinguished men appointed by the Air Ministry. They say that several important conclusions can be drawn from the evidence given. One is that the transportation of passengers and goods alike is apt to come forward spasmodically; that there does not seem to be any deep-seated confidence on the part of the public in these services. I think that has been overcome. The report of a minority of the committee states that it is not in favor of subsidizing any air company. The majority of the committee advocated a subsidy but this was no adopted.

ADRIAN VAN MUFFLING:—Alluding to lighthouses, just what is their appearance in daylight?

PROFESSOR WARNER:—They have ground-marks all along the route and they are painting the names of the towns all along these routes. Some of the lighthouses are of the form adopted for marine work, with a Fresnel lens directing the rays into the upper quadrants. That has not been altogether satisfactory, and it seemed that better results would be secured by using a searchlight. A single searchlight beam shot into the air can be seen at a distance of 40 miles. I am told that even above a bank of clouds the glow of a searchlight can be seen.

MR. UPSON:—It gives better results to play the searchlight beam around.

PROFESSOR WARNER:—Yes.

E. A. SPERRY:—The vertical high intensity searchlight beams we furnished the Army can be thrown above the fourth layer of cloud. A beam has been seen at a distance of 130 miles when it is waved back and forth. These beams will probably constitute the great beacons for night flying. They are very powerful, the 60-in. giving a light of about *one and one-third billion* candle-power.

PROFESSOR WARNER: — Would that be practicable? Would it be a thing we could afford to run regularly?

MR. SPERRY:—A 60-in. beam has been seen probably farther round the earth's curvature than any light heretofore produced. It requires only 150 amp. at 74 volts, a positive carbon ⅝ in. in diameter and a negative carbon 7/16 in. in diameter. It produces 150,000 cp. raw light without a condenser or reflector.

AERIAL TRANSPORTATION OF THE IMMEDIATE FUTURE

BY RALPH H. UPSON

THE author gives an outline of the fundamentals and divides the subject into a discussion of what aerial transportation facilities we have at present and what should be considered for the future, stating that the inventors must determine how far they can go in providing equipment.

The first question regarding new equipment is, "Will it work?" The next, "Is it safe?" Safety is described as being purely relative, the statement being made that there is no such thing as absolute safety. There is no need to expect danger. We must have both speed and safety and making aerial equipment safe is well worthwhile, no matter at what expense of money and effort.

As to whether commercial aviation can be made to pay, economically and so far as society as a whole is concerned, this is a relative question depending upon the length of haul and the mileage cost.

Charts are shown and methods of obtaining basic costs described, together with formulas and coefficients so obtained. These are worked out for both airplanes and airships. Other charts giving the yearly operating costs of airships, their capital expense and cost curves, and the size of airships required for given cruising radii are shown and explained. The speed and cost data for cargo of varying time value carried over various distances, and the cost of freight transportation, are presented in additional charts. [To be printed in an early issue of THE JOURNAL]

THE DISCUSSION

C. D. HANSCOM:—As I understand it, Mr. Upson has compared the future airship with the present-day steamship, railroad and airplane. Would it not be better to compare the airship with the same period of development of the other means of transportation?

R. H. UPSON:—I have been very liberal, particularly with the airplane. The cost which I have worked out for airplane transportation is less than one-tenth of what is being paid by the United States Aerial Mail. The airship costs are based on airships of present sizes, with a variation only in respect to the possibilities of size. It is wholly a matter of engineering that I am bringing up; not one of invention or of new discoveries.

MR. HANSCOM:—It seemed to me there was the possibility of cutting the cost to one-quarter.

MR. UPSON:—I have assumed an airplane with a gross limit of 15,000 lb., which is rather big for present-day service, and I have taken the most favorable estimates of efficiency for that purpose.

MR. HANSCOM:—That would approximate the conditions they have with the aerial mail.

MR. UPSON:—No; the aerial mail is costing over 10 times as much.

PROF. E. P. WARNER:—It is very desirable and necessary that night services be put into effect. I would like to know how Mr. Upson reconciles his advocacy of the single-engined plane with the desire for night flying.

MR. UPSON:—I was merely citing some interesting personal observations of particular planes that have come within my field of experience. I hold no brief, necessarily, for the single-engined machine; it is all a matter of suitability and design. If we are going over a country where it is of the utmost importance to have

reliability and it cannot be had in any other way, we can multiply the number of power units.

Major L. B. Lent:—The Aerial Mail Service has been running between New York City and San Francisco since September, 1920, with several stations in between, and other branch lines, between Chicago and St. Louis and between Chicago and Minneapolis, have been running. We have been keeping accurate account of the cost of this service. While the Army and the Navy have been very good to us in supplying needed equipment, the cost of all the equipment is charged against the Aerial Mail Service and the Post Office Department figures, which are available to everyone, are accurate and can be relied upon. The cost, as we figure it because of our variable loads, runs about 70 cents per mile the year around. With proper equipment and an organization which might be developed that would be unhampered by law and regulations, I think that cost could be cut in half.

Our experience has taught us that the only excuse at present for a multi-engined plane is to get that plane from one major stop to another without a forced landing. We have forced landings from two causes, the weather and engine trouble. I think we should change from one engine to three. If one engine of a two-engined plane quits, we have lost 50 per cent of the power. If the plane is fully loaded, we have not enough power to drive the machine on to a major station where it can be landed properly and taken care of. Right there is an item of the cost of our Aerial Mail Service that is enormous, in comparison with actual operation cost. This maintenance and repair cost is much higher, including bringing in the machines from forced landings, when it is impossible for them to get out or they are damaged in getting them back to a repair station, replacing parts and putting them in flying condition. The other large maintenance cost has already been brought out. The planes we are using today are revised war-planes. The trouble we have in keeping these planes in flying condition is unbelievable, unless one encounters it from day to day. We have to deal with it because we are flying in all kinds of weather. Our performance is from coast to coast; it has not been as high as it might have been.

In speaking of the types of carrying plane, I think it is better, from the commercial standpoint, to divide the load between a number of single-engined planes. If the total load is carried in one plane and it has a forced landing, the whole service is delayed; while, if the load is distributed among four planes and two get through, at least one-half of the service has been performed. Where aerial trade is predicated on delivery of goods within a specified time, the customer demands that those goods be delivered.

Returning to the question of maintenance, the Society of Automotive Engineers has a work to do which I think is most important and that is practically to clean up the present type of plane so that it will be reliable. In a small way the Post Office Department is trying to do this. Usually engine failure is not due to faulty design but to the auxiliaries of the plant such as shaky radiator fastenings, small gas leaks and ignition apparatus out of commission. When coming in out of the snow, a rudder might be ripped off and so on. There is no more excuse for an unreliable gas system in an airplane than in an automobile. That part of the airplane must be made reliable. When those little things that are sources of constant annoyance shall have been cleaned up, we will have an airplane that has a fair amount of reliability.

The Aerial Mail Service has been running about 2½ years. If we could proceed as we would like to proceed, we could accomplish many things that we cannot accomplish now. But the record of the Aerial Mail Service will show that commercial aviation is a real, practical problem. The cost is not excessive and it can be reduced readily. I am informed that there is a large volume of business which can be had and would pay rather good dividends on the cost of operation. It may not come in the very near future, principally because the landing fields and routes have not been laid out. Places to land, places to take care of the machines and a complete organization equipped with repair shops and all paraphernalia on the ground are necessary to keep a line in constant operation. There is a vast difference between fair-weather flying when it appears desirable and running a commercial aerial line on a schedule. Ability to fly in any weather will come, I think, very shortly. The one thing that hampers us now in flying is having to wait for good weather. The pilots will not go above the clouds and fly because they do not have the necessary navigating instruments to find their way. Wireless apparatus is available which will enable a pilot to fly above the clouds and come down and find his field. He actually can talk to the stations and find out where the landing field is. We have done that. In landing at night, the incoming pilot can notify the landing field and flyers can be sent out to meet him, even long after dark. Until we can fly above the clouds and disregard landmarks we will be handicapped in commercial work. The pilot flying over the Allegheny Mountains flies under the clouds, practically brushing the treetops all the way from New York City to Cleveland. That may be all right for carrying mail, but passengers cannot be carried in that way. The next step in real development is to secure more reliable planes by paying attention to the auxiliaries. I think we are not very far from such accomplishment.

COMPRESSION RATIO AND THERMAL EFFICIENCY OF AIRPLANE ENGINES

BY S. W. SPARROW

APPRECIATING the fundamental relation of the compression ratio to the thermal efficiency, the National Advisory Committee for Aeronautics sponsored a comprehensive investigation of this subject at the Bureau of Standards. Every effort was made to measure the engine performance so completely as to make possible an analysis that would not only explain the results of this particular series of tests but form a sound basis for predicting the effect of changes in the compression ratio on the thermal efficiency of any engine. The experimental work is as yet incomplete and only some of the more salient results are presented in this paper.

An eight-cylinder airplane engine was used, having pistons allowing compression ratios of 5.3, 6.3, 7.3 and 8.3. The differences in compression ratio were effected by crowning the piston-heads different amounts. The tests were made in the altitude-chamber to secure typ-

ical altitude conditions of air temperature and pressure, and those presented in this paper were made under full load at an engine speed of 1600 r.p.m. The resultant data are exhibited in charts and these are analyzed. [Printed in the March, 1921, issue of THE JOURNAL]

THE DISCUSSION

O. C. RHODE:—What kind of fuel was used in the Bureau of Standards' engine tests?

S. W. SPARROW:—Aviation gasoline was used in all of the tests.

GEORGE W. LEWIS:—The National Advisory Committee for Aeronautics is, of course, very much interested in the development of commercial or civil aviation. The whole future of the aeronautic industry is dependent largely upon the proper development and encouragement given to it at present. The National Advisory Committee for Aeronautics has laid out a tentative program for a civil airplane contest. The rules and regulations for the contest are strongly recommended by Professor Warner, who has spent two weeks studying the rules, regulations and actual operation of the British commercial airplane competitions.

One of the most important, if not the most important, development in connection with civil aviation is the establishment of landing fields for airplanes. Captain Hartney recently presented a report in Washington giving outlines of a program of the Army Air Service for establishing an airway between Washington and Dayton, Ohio. The airway will provide not only for airdromes but emergency landing fields and markers so that the pilot can at any time determine his exact location. The airway will be laid out so that it will be possible for a pilot who has never gone over the course to make the trip without the usual delays. The Army Air Service also expects to provide means for flying over this course at night. The establishment of this particular airway will make it possible for the Army to use a number of excess steel hangars that are now in stock, as they can be erected at the different landing fields along the airway.

HIGHWAY-ROAD CONSTRUCTION

BY W. E. WILLIAMS

STATING that asphalt, brick and concrete-slab road-surfaces are the only pavements that have given satisfaction for automobile traffic, the author believes further that thus far the concrete-slab surface is the only one worthy of consideration for such traffic. He discusses the merits and demerits of these surfaces and includes an enumeration of the factors that combine to produce a thoroughly satisfactory road surface.

Passing to a detailed review of the bearing value of soils and the correction of road failures, the author presents data and illustrations in substantiation of his statements and follows this with a consideration of the reinforcing of a concrete road slab with steel.

Regarding the ultimate highway, it is stated that a concrete-slab road, about 8 in. thick and of uniform depth across the road, perhaps with an increased thickness of integral supporting curb-block on the edges in some locations, is the type of road that should be built in this country, and reasons in support of this are given. The subject of impact is discussed and its meaning explained. [Printed in the February, 1921, issue of THE JOURNAL]

VARIABLE FACTORS IN HIGHWAY DESIGN

BY H. E. BREED

IF prospective traffic, soil conditions, drainage, surfacing, maintenance and political influence were definitely known quantities instead of being algebraic unknowns, the problem of highway design would be simple; but all are variable and we can measure them at present only by empirical generalizations. Neither ignorance on the engineer's part nor carelessness or fraud in construction is the cause of many of the highway failures; the variable factors involved simply defy the best opinion and practice obtainable.

The factors governing the most desirable type of pavement, prospective traffic and cooperative methods between highway and automotive engineers are then considered, followed by comments on the subjects of road foundation, drainage, surfacing and maintenance. The subject of political influence as it affects highway departments is discussed at some length, the evils of such influence when it is detrimental are emphasized and remedies for them are suggested. [Printed in the March, 1921, issue of THE JOURNAL]

AUTOMOBILE OBLIGATIONS TOWARD HIGHWAY DEVELOPMENT

BY H. W. ALDEN

THE author brings to attention very emphatically the responsibility of the automotive industry for some things besides the actual building and selling of motor cars.

The progress of civilization can be measured very largely by advances in means of communication. The transfer of messages by wire and wireless has made wonderful advances of a fundamental nature in recent years, but the transportation of commodities from place to place has not made such strides. The automotive industry has been concerned mostly with the actual development and production of the motor car and, as an industry, has stopped there without developing those allied activities which are vital to the long-time success of the business. The railroads afford a good example to follow in principle. Their roadbeds and the equipment operating thereon have been improved and developed hand-in-hand by the same general guiding influ-

ences and their wonderful advance in both is due fundamentally to this unified control of these two elements. A different condition exists to-day regarding highway transport. We have far better highways than formerly, but the author believes that the ratio between the demand on the highways and their ability to meet that demand has gone down rather than remained constant.

After expressing his sympathy with the difficulties confronting the highway engineer, the author rehearses the factors governing merchandise transportation and outlines means of betterment that should be promulgated by automotive engineers, with special reference to the construction and maintenance of highways for motor-vehicle use. [Printed in the February, 1921, issue of THE JOURNAL]

INVESTIGATIONS OF ROAD SUBGRADES

BY A. T. GOLDBECK

THE problem of the subgrade is evidently that of finding what causes certain kinds of subgrade material to be soft and of very low bearing value and, having ascertained this, to determine what means must be employed to either remedy the condition of the subgrade or fit the design of the road surface to the subgrade. The author considers the mechanics of the problem and some of the various factors involved in producing an unstable condition in the subgrade.

The paper is illustrated with charts plotted from data obtained relative to the bearing power of soils, intensity and distribution of pressures, various forms of road construction in connection with the principles underlying the drainage of subgrades and impact tests, The road tests made at Camp Humphreys are described. Soft subgrades are considered at length; the drainage problem in general is discussed and results of laboratory investigations of subgrades presented. Bearing value tests of soils and drainage investigations are next considered specifically. [Printed in the April, 1921, issue of THE JOURNAL.]

THE DISCUSSION

CHAIRMAN H. W. ALDEN:—I doubt if there has been a time in the history of the automotive industry when it was as necessary as now for it to get out of its so-called legitimate line of work and pay attention to some other things. The matter of how highways shall be built must be left largely to the highway engineer who has been trained for that work, but that does not relieve the automotive industry of its responsibility to turn to and help. While I have been rather severe in my criticism of what the automotive industry has done in the past, I think it is well borne out by the facts and that we have not done our share by any manner of means. The same thing is true about the handling of merchandise. We build trucks and sell them to dealers to operate with no particular attention given to their correct and logical use, except in a very few cases, as at Cincinnati and Cleveland, particularly in connection with other transportation facilities.

W. E. WILLIAMS:—The term "hammer-blow," in place of "impact," will be better understood by the layman as a road-destroying factor. "Hammer-blow" was the term in common use with railroad track men years ago. As it relates to brick pavements, the hammer-blow of the iron-tired vehicles and the shoes of horses soon breaks off the corners of the bricks of the best laid brick pavement, until it becomes a continuous series of offsets producing vibration on the vehicle wheel treads that injures both the road and the vehicle. That the drainage should be good is so axiomatic that I need not dwell upon it. If it were possible to have a dry subbase, a thin hard surface would be sufficient.

CHAIRMAN ALDEN:—Mr. Williams has, to my mind, put his finger on the solution of the highway difficulty, but I do not agree with him that it is in limiting, within so-called reasonable ranges, the weights of vehicles. I

question very much whether the present-day trucks are heavier than the well sub-soiled road is perfectly capable of standing. The Federal Highway Council has done much work along this line and has started to accomplish some very remarkable results in the coordination of various organizations working toward the end of improving the subgrade. They are finding out some very remarkable things. As Mr. Williams says, moisture in the subgrade is the enemy of the road. It is beginning to be apparent, however, that it is perfectly possible with proper knowledge and precaution of the soil in which the road is to be placed, to get vastly increased supporting power of the subgrade from what had been current practice today. In nearly every case where a failure occurs, the bearing power of the subgrade has been criminally low, much lower than necessary under the conditions confronted. This is not meant as a criticism of the highway engineer, because he also has had other problems to meet.

S. W. WILLIAMS:—A number of nationally known organizations, such as the American Automobile Association, the National Automobile Chamber of Commerce, the Federal Highway Council, are earnestly and conscientiously attempting to solve the difficulties obstructing highway development. It is somewhat of an undertaking and is discouraging, but we are encouraged when an organization such as the Society of Automotive Engineers cooperates with us.

I have listened with greatest interest to the papers presented and discussed here today and I am much impressed. I am in entire sympathy with Mr. Williams in that we need roads, that we need more roads and that we need them just as fast as it is possible to build them, but I doubt very much if we want to begin to fit this new type of transportation to the road or highway rather than the highway to the transportation. A prominent highway engineer said in my presence recently that no highway engineer in the United States today knows how to develop a highway that will serve the transportation needs of the country 5 to 10 years hence. I believe that an analogous condition prevails in this Society. I doubt very much if automotive engineers have made up their minds that they know the type of vehicle that will serve the needs of this country. We fail to realize that the highways of this country have an earning capacity, and that earning capacity will be increased with the economic service rendered. Therefore, the real controlling factor in both the highway and the vehicle will be the transportation needs of the communities. We are not in a position to say today what we shall build, nor should we encourage the public to believe that we should curtail beyond a certain reasonable limit the capacity or the type of truck that will be or should be used on the highway.

Mr. Goldbeck covered his subject in such a thorough manner that I can add only that the word drainage has

come into such common use in this country that I am afraid it has been misused. I am satisfied that engineers are awakening to the fact that the real necessity is not to take the moisture out of a road, but to keep it out and away from the road. If we do that, we will have dry surfaces, in a short time dry subgrades, and in a little while longer we will not hear any more talk about the size of the truck that will use the road, because the dry road will stand the weight. I am satisfied that so far as is possible in reason, without handicapping the needs of the communities, we should attempt to protect the roads that we have already constructed until we are able to build the roads to meet a greater need.

Mr. Breed referred to the political situation. Unfortunately, the position of the State highway engineer in this country has been made a political football. We must obviate that, but we cannot do this until the public awakens to the seriousness that surrounds such a custom. I am not criticising any other State more than I am the State I come from. Only a short time ago a change in administration took place there. Immediately there was a change in the State highway officials. That change was brought about by a change of governors. Politics was allowed to come into the situation so completely that the new administration refused to confirm the appointee of the other party. I condemn that, notwithstanding that I belong to the political faith that was guilty of the act.

In regard to national legislation, unfortunately the views in Washington and of those throughout the country differ; some are striving for one thing and some for another. It is rather difficult to say at this time what the outcome will be. The different agencies that are represented and that have been working for months are conscientiously trying to get together to solve the problem to the best interest of all, and we are hoping to establish at this or the next session of Congress a separate responsibility in an administrative organization by which the highway problems will be handled. We believe, in view of the large expenditure of money involved, the millions already available and the many more millions to come, that the time has arrived when the highway-building responsibility of this country should be centered in a board responsible to no other department of the Government; in others words an independent board.

Considerable reference has been made in newspapers and in publicity matter to the fact that we have today between $700,000,000 and $800,000,000 available. It is creating some amazement among the people that we have such a large amount of money. It will be unfortunate if that opinion becomes general, because that sum is simply an accumulation over a period of practically 3 years. When the highway needs of this country are considered, it is a small sum comparatively. The day is coming when we must spend that much, if not more, to meet the transportation needs.

A MEMBER:—In 1872 I did some of the first work in New York City with asphalt pavement. In 1866 Carroll Beckwith investigated road building in France and made a full report to the United States Government. Attention was called to the good results in the use of asphalt. Some years ago Mr. Williams, of Washington, stated that the railroads were not helping road-building. I took exception to that. I take exception also to the statement that automotive engineers have not done an immense amount of work for road improvement.

In 1908 I was appointed consulting engineer of the Quaker City Motor Club. In that year we had the great-

est race that was ever known in the United States, in Fairmount Park. We had a large number of visitors. Marvelous improvements have been made since that date, but I wish to emphasize the fact that I have had during my career very splendid assistance from the people interested in automobiles and in motorization. One of my family, James Boardman, was largely instrumental in establishing the railroads of the State of New York. I wish to be instrumental in helping to establish the great motor roads. Motorization is absolutely the requirement of the day. When the late President Roosevelt asked what the best thing was for the uplift of the farmer, a number of points were mentioned but I replied "good roads." We must have good roads and we must have roads that can carry this motorized transportation system. Just after the close of the war, Mr. Morse, who had had charge of the railroads for the Government, said that the railroads were not adequate by any manner of means for the transportation of today. He stated that there are a number of railroads that cannot pay for their own maintenance. He suggested that the rails be removed and that these old railroads should be converted into roads.

I disagree with Mr. Williams' statements. Several years ago I stated at the Philadelphia Engineers' Club that there were at least 20 different types of road that could be made absolutely serviceable. There is nothing better than granite for certain places. While I confess my preference for asphalt, there are at least 20 different classes of road that can be and are being built today. I think I am about the oldest man engaged in highway construction. I appreciate what has been done by the engineers connected with the production of automobiles and engines in the way of road construction. I think they are doing magnificent work. We all gratefully acknowledge the aid that we have had from the people in the automotive industry.

CHAIRMAN ALDEN:—The automotive industry appreciates the courtesy of the foregoing compliments, but I think it has not done anything like what it should do and what I feel very sure will be done in the next few years. There are indications that the railroads, the waterways and the highways are being brought together now in a way that is most gratifying. This meeting has been devoted largely to the road end of the highway question. We shall probably have at the Summer Meeting a session devoted entirely to the question of transportation, so far as the getting together of the railroads, the motor-car companies and the highways engineers is concerned, for consideration of the municipal and terminal transportation of goods and merchandise.

DAVID S. LUDLUM:—Will Mr. Goldbeck say how many different makes of chassis were tested in Washington?

A. T. GOLDBECK:—According to my recollection, there were from six to eight.

MR. LUDLUM:—How far do you expect to go before you recommend one design of chassis?

MR. GOLDBECK:—We do not expect to go that far. We are simply trying to find out how much pressure and how much impact are exerted on the roads, due to the different weights of vehicles. We feel that the thing to work for is the rational design of pavements. If that is so, one of the fundamental things to discover is how much load is being exerted on the pavement. Therefore, we are trying to use as many of the heavy trucks as we can, and I think that we have used a sufficient number.

MR. LUDLUM:—Have you tried a truck with a short wheelbase? One company has advertised broadcast its

deductions from what you have said. I am curious to know whether you have tested out a short wheelbase and the drive through the rear springs without torsion rod?

MR. GOLDBECK:—I think we have not.

MR. LUDLUM:—That was offered to you last summer. I am wondering how far your department is going in the public press before you have tested out everything to find out how much is involved in the way of investment in motor trucks in this country.

MR. GOLDBECK:—It is almost necessary for us to get out progress reports. I would prefer to finish the investigation and come to definite conclusions before issuing any report. In fact, we have been trying to go rather slowly; we could have published some additional information some time ago, but we have been holding it up. However, we cannot hold it up very long. We are entirely willing to test any make of truck; in fact, if it is thought that any particular make will have any influence on the design of roads, we want to test that make.

CHAIRMAN ALDEN:—Perhaps the Bureau of Public Roads would send to the National Automobile Chamber of Commerce copies of each of its reports. Then those concerned could govern themselves accordingly.

MR. LUDLUM:—That would be satisfactory.

R. A. MEEKER:—Some things have been left unsaid. It is true that drainage is an essential feature in the construction of all roads; however, sometimes an engineer is condemned for faulty drainage when it is not his fault. The American public has an idea that it is only necessary for us to build a road and we can then go away and forget it. It is just as essential that a road should be maintained and carefully watched as that any motor vehicle should be carefully maintained. Where would the motor truck be if it were not maintained properly? Along the same line of reasoning, very many people condemn roads. The foundation of a concrete road should be resilient to a certain extent. There is no resiliency in a slab of concrete. It is "as hard as a rock." It will break under impact. It seems rather strange that in designing concrete roads we have neglected all that we learned in designing concrete sidewalks. No man would think of laying a concrete-slab sidewalk without carefully excavating the earth underneath and filling in with some pervious material such as cinders or sand, thus making a cushion for the slab, but who does that with concrete roads? The roads fail and then that type of road is condemned.

Some years ago one of our county engineers was taking up an old stone road. I suggested that he take everything out of the road, bring the subgrade to an elevation about 3 in. above the finish of the subgrade and then plow the whole thing from side to side. He doubted this. However, he tried it. Now there is a concrete road 3½ miles long that has no cracks in it except in two or three places, and those are due to neglect of the drainage. The underdrains were put in and the road was properly drained, but they were broken and nobody repaired them. When the underdrains were examined they were found to be mashed in.

After a road is built, constant and minute attention must be given to it just as in the case of a motor truck. If that is done, good results will be obtained and there will not be so much complaint that roads are not strong enough to carry the loads. If the road is to be taken care of and the drainage properly looked after, we need to follow the old plan of the railroads of having section gangs and track walkers. Place the gangs in the spring and in the fall, have them go over the road and fix up

what is necessary. Then assign from 3 to 5 miles of road to a man and keep that man on it as long as the road is in good condition. If his section of the road goes bad, get another man.

A MEMBER:—Mr. Williams states that experience has proved that an asphalt surface will not stand up under heavy truck traffic. The service records of asphalt pavements throughout the country, on both rigid and nonrigid bases, are contrary to this assertion. Like any other pavement, the serviceability of asphaltic types depends largely upon the support furnished the pavement from below. Mr. Williams apparently pins his faith to the beam strength of rigid pavements and states that asphalt surfaces aid a concrete base but slightly in sustaining beam loads. In this connection it is rather significant that many miles of rigid pavements which have failed under heavy motor-truck traffic, are now being successfully salvaged as foundations by laying an asphalt wearing course upon them. This, I believe, is the present practice in Maryland. As a matter of fact, asphalt paving mixtures not only possess considerable beam strength but greatly increase the beam strength of the rigid types when subjected to impact, which is recognized as the most destructive traffic agency on a pavement. This fact has been demonstrated by recently conducted tests the results of which were published in the *Engineering News-Record* for Dec. 30, 1920.

I believe that if as much attention were paid to the suitable preparation of subgrades as to the increase in the massiveness and strength of pavement design, our paving problems would be solved much more quickly and economically. It is not believed that rigidity in the design of pavements is any more logical than in the design of motor trucks. The motor truck itself, as well as the load it carries, is logically protected from the shocks of traffic by rubber tires and springs. No one would for a moment believe it advisable to construct a perfectly rigid truck and increase its massiveness of design to withstand the destructive agencies of traffic. Why then should such practice be recommended in the construction of highways?

D. C. FENNER:—Mr. Williams' paper states that on the heavy-capacity trucks the wheel load runs from 4 to 8 tons, which is supported upon a tire area of 48 sq. in. Partly to satisfy my own curiosity in that respect, I took a 7½-ton truck equipped with 14-in. rear tires, placed the truck on a concrete slab and reduced the pressure to 105 lb. per sq. in.

H. W. SLAUSON:—One of the interesting features of Mr. Goldbeck's paper is his reference to the effect of differences in inflation pressures of pneumatic tires, in regard to impact pressures. I understood him to say that there was no difference whether the tires were pumped to 110 or 160 lb. per sq. in. My interpretation of the effect of impact has been the absorption by the tire of the hammer-blow struck by the loaded wheel when it travels through the air and strikes the road. We all think that an under-inflated pneumatic tire rides more easily. If that is the case, why is the impact the same? Are we wrong in thinking that an under-inflated tire rides more easily, or is there a difference that is not observed with the truck?

MR. GOLDBECK:—An under-inflated tire does ride more easily and, as a matter of fact, the tests do show a somewhat higher impact for the more highly inflated tires. In regard to the theory of impact and what we mean when we speak of impact, we know that there is an old law in physics which says that a force is equal to the

mass times the acceleration. This means that if we have a weight at rest whose mass is M, and we act upon that weight with a force F, thereby increasing the velocity of that weight from zero up to a certain maximum velocity in a given time, we will have accelerated or changed the velocity and that is this quantity A. We can see readily that the shorter the time required to change the velocity from zero up to a certain maximum, the higher will be the quantity A, because the acceleration is equal to the time-rate of change of velocity. The higher the acceleration is, the mass remaining constant, the greater the force exerted on the road surface will be.

What do we have when a truck tire strikes the road surface? We will say that the tire is just about to fall from one level to a lower level. The tire strikes the road surface and begins to flatten out. At this instant there must be a reaction created between the road and the tire. The flatter it becomes the greater that force will be. In other words, we have a variable force acting between the tire and the road surface, depending upon the extent to which the tire is flattened out. Suppose one tire flattens out much more than another, in bringing that load to rest. This generally means that there is a longer time required to bring that load to rest; a longer time means smaller acceleration, because acceleration is equal to the velocity divided by the time. The longer the time is the smaller this quantity A will be, and the smaller the acceleration; so, the theory shown that the greater the deflection of the tire, the longer will be the time required to bring the unsprung weight to rest and the lower the acceleration, and, from this formula, the lower will be the force exerted on the road surface.

That is not the only force exerted on the road surface in the case of a truck wheel because, when a truck wheel strikes the road surface, it is influenced not only by the force of gravity but by the compression in the spring; so, we must add to that the quantity C, which is the amount of compression existing in the spring at the time the truck tire comes to rest. This whole question of impact is merely one of the time required to bring the weights to rest in a vertical direction.

CHAIRMAN ALDEN:—The curves did show a difference between 110 and 160 lb. per sq. in. It is not negligible. This question of the time element and the yield is a very important one.

W. E. WILLIAMS:—From some of the statements made, this audience appears not to be closely in touch with the men who are building and supervising roads. Road engineers would like to build the very best roads in the first instance and to be able to say that they are permanent highways, but the cost will not permit that. When we began to build railroads in this country, one railroad built on this basis was an example of a splendidly constructed road, but it nearly bankrupted the country.

If one goes into the history of the financing of our railroads generally, one will find that what I have said about cheaper roads and large mileage is true. Legislation is bound to be passed to do exactly what I have outlined about limiting the heavier loads.

In regard to the matter of upkeep, Mr. Meeker had a clear idea of what a road really requires. Let me go a little further. The railroads have been long enough in this country to have had technical attention that represents 25 to 50 per cent more work than the highways have had. A railroad cross-tie can be treated to extend its life, but a time arrives when the cost of that cross-tie is not a good investment. It is better, at some cost, to renew it and to put in a cheaper cross-tie. The same

thing is true in the matter of the first cost of building highways. We had better build a cheaper road and put on watchmen to keep off the destructive loads. A $7\frac{1}{2}$-ton concrete-slab road costs about $40,000 per mile in our region. It is better to keep repair gangs in maintenance service than to increase the first cost for a stronger road.

In regard to impact, all of the talk here about impact has referred to the road after it has broken down. Mr. Breed has said that impact does not amount to anything until there is a drop in the road. When we have a fault, say a 2-in. drop, it is no longer a road. Send for the section gang and do not calculate that tires or anything else will save it.

It matters not how much area of tread-contact tires have on the road; it is the total load on the axle of the wheel that counts. For brick surfaces and concrete surfaces withstand more pressure per square inch than will the rubber of the tire. It has been related here how a broken-down road was saved by putting on some asphalt. That did some good but it would have been better if a wire brush had been run across its surface, if it had been thus scraped clean and if concrete had been added. Some of the experiments that the Government is conducting relate to things long well known in civil engineering, yet this may be necessary to bring the facts sharply to the attention of the public.

As to a porous sub-base, it is a fine thing, but is it the best thing? What we are after is the best thing for the least money. To use a 4, 5 or 6-in. sub-base of sand or any other porous material, is not a good investment unless that material is easily obtainable. Where rock and sand must be hauled many miles, they are not a good investment. It is better to increase the depth of the concrete block at the same cost as that of the porous material and thus get the strength benefit of the square of the depth.

S. W. WILLIAMS:—We are not building roads in this country with any knowledge of traffic. We went before the Legislature of Ohio two years ago and asked for authority to employ a traffic and sub-soil engineer. The matter was so little understood that we could not get the necessary authority. The average road in this country is sold from the standpoint of the material salesman on the job, and not from the standpoint of the traffic. I believe Mr. Breed will agree with me that 80 per cent of the roads in this country have not been built with a knowledge of traffic conditions. We are building in some places away beyond the needs of the traffic. In other places we are building roads that do not meet the needs of the traffic. We should build roads that will take into consideration the traffic, regardless of what material the roads are built.

HARRY MEIXELL:—The State of New Jersey contains more than 500 separate and distinct governmental units. These comprise 21 counties, 235 townships, and over 250 cities, towns, villages and boroughs. In each of these governmental units there is one form or another of highway control. These local highway authorities exercise almost absolute sway over the 20,000 miles of highway which lie within the State's borders. They can improve their highways as they see fit and maintain them or not as they see fit.

This complete decentralization of highway control is the keystone to the answer of the whole problem with which we are wrestling. How can these local authorities be subordinated to intelligent centralized direction and control, or, if this is too much to ask, how can the lessons which we are learning day by day in regard to high-
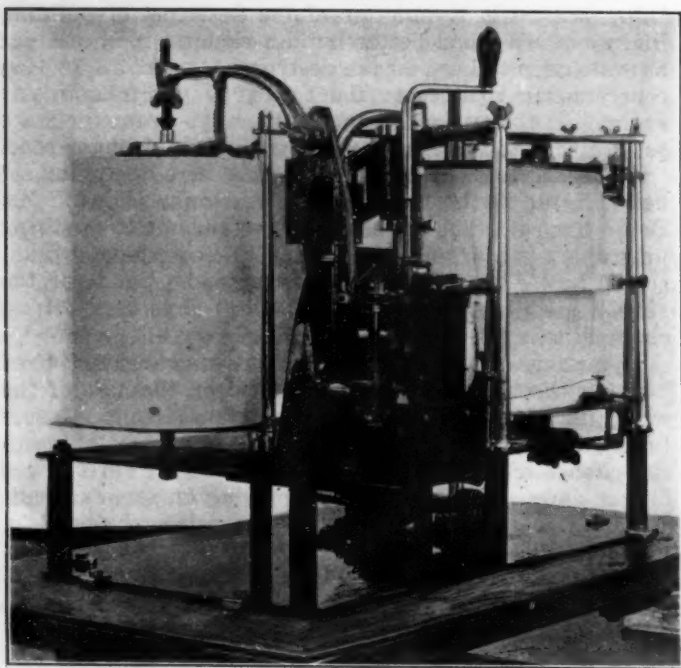
FIG. 1—A NEW FORM OF VEHICLE SEISMOGRAPH

ways be passed on to these 500 separate and distinct groups of municipal authorities?
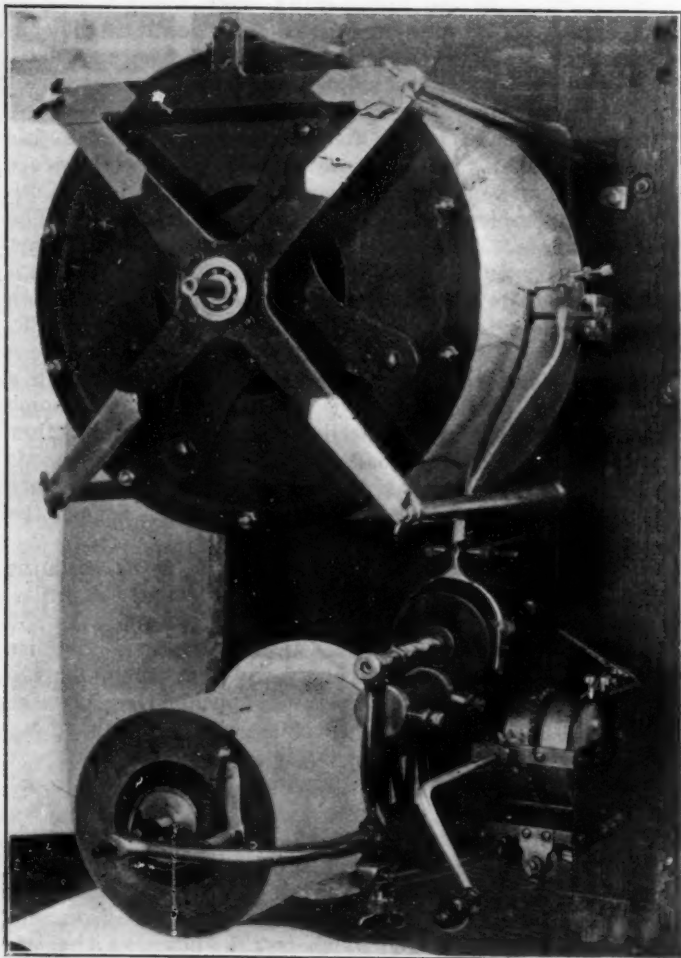
Let us assume that to meet the highway transporta-

FIG. 2—VIEW LOOKING DOWN ON THE SEISMOGRAPH

tion needs of New Jersey a total of 3000 miles of main arteries of travel will be necessary, although this is a very liberal estimate. Are the highway resources and energies available in New Jersey being concentrated upon these 3000 miles of highways? Is the improved road mileage being located in the very best way to meet the greatest economic demands of that State? Not a bit of it. What is being done? The 500 separate and distinct groups of highway authorities are trying frantically to obtain good roads within their own borders and in their efforts are endeavoring to reconstruct about 10,000 miles of highway. The highway authorities are not cooperating and coordinating for the accomplishment of the same definite and predetermined end. Each municipality wants good roads in its own community and, without attempting to find out whether such roads will link up with the State highway system or with the highway systems of its neighbors, it simply goes ahead and builds the roads.

For the sake of argument we will assume that a heavy-capacity improved road will cost on an average of $50,000 per mile under present conditions. At that rate the 10,000 miles of highways which the local authorities of New Jersey are striving to improve would cost $500,-000,000. Since the work of highway reconstruction should be accomplished during the next decade, it is obvious that the taxpayers cannot stand such an enormous burden.

In consequence, it is imperative that legislation be enacted so that these local jurisdictions which are so numerous are deprived of their right to do as they see fit in the location of improved highways, the determination of their structural standards and in the building and maintenance of them. They should all be obliged to combine their efforts with some centralized control so that State highway systems, connections therewith and extensions thereof can be laid down to meet the greatest economic needs of the community. This is a tremendous problem to solve, but it must be solved if we are to obtain the largest possible returns from the scores of millions of dollars that are pouring into the highways of our States every year.

A MEMBER:—I cannot agree with one statement Mr. Williams made. He says, "A concrete-slab road about 8 in. thick and of a uniform depth across the road, perhaps with an increased thickness of integral supporting curb-block on the edges in some locations, is the type of road that should be built in this country." Again he says, "In my opinion the automobile vehicle world will profit by laws that prohibit anything above a 5-ton load."

The limit for any concrete road now built is about 8 in. That certainly is the practice. There are a few stretches in New Jersey and one that I know of in Ohio that are 10-in. roads. The most prominent we see out West is the Wayne County road. These roads have been standing up under the most severe loads. I believe that an 8-in. concrete road need not be restricted to 5-ton loads. There are very few road failures, compared with the enormous mileage of 8-in. concrete slabs under loads heavier than 5 tons.

MR. MEIXELL:—The International Traffic Officers' Association took Section 4 of Article 9 of the Proposed Uniform Vehicle Law endorsed by the Motor Vehicle Conference Committee and made several additions to it. The Proposed Uniform Vehicle Law recommends in the matter of restrictions as to weight 28,000 lb. gross weight for a single vehicle of four wheels or less, and advocates a maximum of 22,400 lb. on one axle and 800 lb. per in.

of tire width measured between the flanges of the rim. In addition to the requirements of the Proposed Uniform Vehicle Law, one measure specifies a gross weight limit of 40,000 lb. for a vehicle of six wheels, has a provision limiting the load on any one wheel to 11,200 lb. and recommends 600 lb. per in. of tire width for metal tires. Anyone desiring copies of the Proposed Uniform Vehicle Law and its companion measure, the Proposed Uniform Anti-Theft Law, can obtain them from the Motor Vehicle Conference Committee, 366 Madison Avenue, New York City.

W. E. WILLIAMS:—In Clayton County, Iowa, the citizens realized that their money was not sufficient to build high-class roads. They arranged to have men go out over the roads after every rainstorm and fill up the ruts by using drags and other tools. By filling up the ruts immediately after rains they keep the roads in such condition that there is a greater average use of the motor vehicle and better general highway service. That only accentuates the necessity of watching and keeping the roads in repair. We must do that. Automobile service in this country is limited to the good roads. The traveling man does not use an automobile in soliciting the country trade on account of bad roads. If we had a wider range of hard roads, the use of motor vehicles would be increased greatly.

A. F. MASURY:—The new seismograph designed by Frank Pampinella and me, although simple in construction, records a very complete and accurate history of the comparative vibration of a truck or automobile chassis under the action of different types of spring and axle-load distribution. Differences in spring action, too slight for human detection, are accurately compared. With such a means of comparison, engineers are enabled to choose with accuracy spring suspensions that will transmit the least vibration to the "sprung" portion of the chassis. The 1915 machine has been improved and developed into the present seismograph. It is sensitive to the slightest vibration and records movements that are far beyond human detection. Figs. 1, 2 and 3 and the description give an idea of the construction and operation of the instrument.

Mounted in a rigid steel frame is a metal drum 12 in. in diameter and 9 in. high, driven through a double-reduction worm and gear giving a ratio of 32 to 1. The worm shaft is driven by a flexible speedometer shaft from the front wheels, and turns the drum at the rate of one revolution per mile of travel of the truck. On the upper edge of the drum are 10 cams, equally spaced,
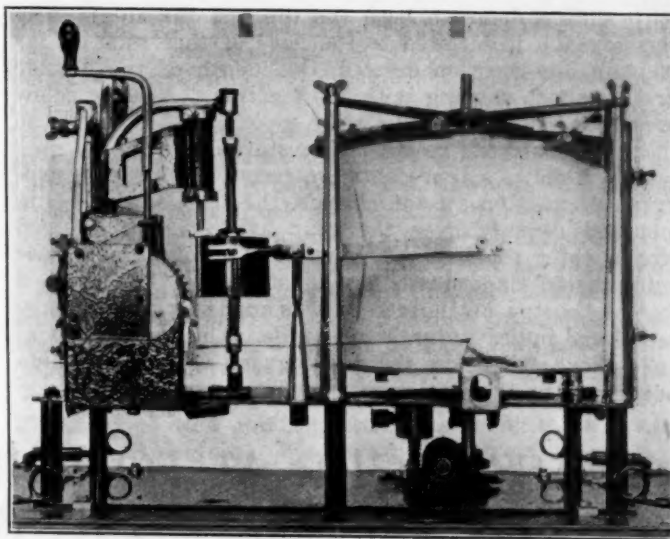

FIG. 3—SIDE VIEW SHOWING A PORTION OF A RECORD AS TRACED BY THE PENCIL

which trip a pencil-holder and record tenths of a mile on the paper which is rolled on the drum. The paper is fed to the drum from a spool at the opposite end of the frame. A phonograph motor is mounted near the recording drum and operates a pencil which marks periods of time on the record. This motor can be governed to record intervals of $\frac{1}{2}$ or 1 min. as desired.

In addition to these two pencils there are two stationary pencils which rule horizontal guide lines on the paper near the top and bottom edges and equidistant from the center. The seismograph pencil is held on a light spring arm pivoted on single-point bearings. On the opposite end of this pencil arm is a slotted fork surrounding a weight which slides vertically on a central post and is actuated by the vibration of the truck. The weight is supported by a coil spring from below and a lighter coil spring above prevents excessive rebound. The weight is further damped in both directions by an air dashpot with adjustable outlets so that the damping effect can be accurately adjusted.

As the weight moves up and down, the pencil at the opposite end of the arm leaves a series of marks on the paper on the revolving drum. The proportionate length of these marks, measured from the guide lines, indicates the comparative vibration of the unsprung portion of the chassis. The entire mechanism is enclosed in a glass case
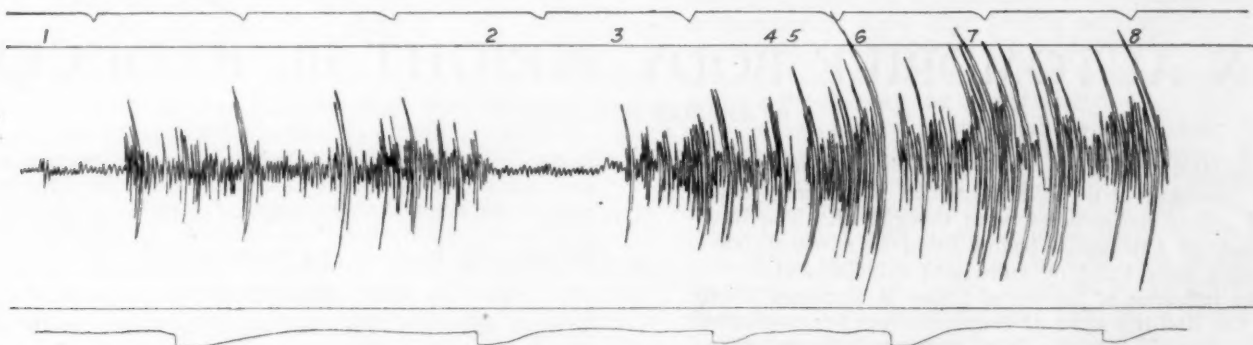

FIG. 4—A TYPICAL RECORD GIVEN BY THE SEISMOGRAPH

From 1 to 2 the Truck Was Traveling over Rough Asphalt at a Speed of 15 M.P.H., between 2 and 3 the Speed Was Reduced to 6 M.P.H. and from 3 to 4 the Speed Was Increased Again to 15 M.P.H. The Break in the Record between 4 and 5 Indicates the Stoppage of the Truck. Between 5 and 6 the Truck Was Traveling over Rough Stone Blocks on a Quay. At 6 All Four Wheels Ran over a 3-In. Obstruction at a Speed of 8 M.P.H., at 7 the Right Wheels only Passed over a Similar Obstacle at 8 M.P.H. and at 8 the Left Wheels Went over a 3-In. Obstruction at the Same Speed

with sliding doors in both the top and the sides. The seismograph is screwed to the floor of the truck or car body in any location desired, the length of the flexible driving-shaft varying with the location. A lever below the glass case throws the worm gearing out of mesh, so that the record can be stopped or started at will.

Fig. 4 shows a representative record from the seismograph as used on a 5-ton chassis, the seismograph being mounted directly over the rear axle. The numbered circles refer to the road conditions encountered, these being listed underneath the illustration. The notched line at the top of the record was made by the mileage pencil and indicates tenths of a mile. The two horizontal lines above and below the seismograph record are guide lines made by the stationary pencil and are used to meas-ure the distance traveled by the seismograph pencil. This is preferable to a central guide line, which would be covered in many places by the seismograph record. The notched line at the bottom of the record is made by the time pencil and indicates minutes elapsed.

The company I represent has been using this instrument for some time in measuring the relative vibration in trucks equipped with standard spring-shackles and a new rubber-cushion spring-support. It has been found that over comparatively rough roads the difference is very noticeable to anyone riding on the truck, but on smooth roads the seismograph recorded a series of vibrations on the standard chassis much greater than those on the chassis equipped with the rubber cushions and which was not noticeable to observers on the trucks.

PASSENGER-AUTOMOBILE BODY-DESIGNING PROBLEMS

BY ANDREW F. JOHNSON

THE designer must know first what purpose the body is to serve, and then decide upon its exterior appearance in connection with the car as a whole. The body is only a part of the car and cannot, in the general scheme, be considered separately. After the shape has been decided upon, the designing of bodies to carry passengers is included under the heads of safety, comfort and elegance, and the factors governing each are considered briefly.

The author believes that the "best" car has not yet been built and that the time will come when the best examples of high-class passenger automobiles will not be of European origin, when the foreign builder of fine cars will tell prospective customers that his cars are as well built and as well finished as the best American car. [Printed in the April, 1921, issue of THE JOURNAL]

THE DISCUSSION

CHAIRMAN W. G. WALL:—This session is unique in that it is the first devoted exclusively to body building and design that the Society has held. The building of bodies for vehicles is an old industry, but the building of bodies for motor cars is comparatively new. Each year we find the body of the motor car becoming of more importance. In the early stages of the automotive industry it made very little difference what type of body we used; in fact almost any body was more or less satisfactory, as we were engaged then in building cars that we were glad to have run at all. Now, although chassis are still a long way from being perfect, the body is assuming more importance. From a sales angle, I would say that the body is probably the most important part of the car. Even the chassis does not offer as wide a scope to the engineering designer as does the body. While some of the bodies that we are building today are remarkably fine creations, I believe that the present basis of body design does not rest on as firm and permanent a foundation as it should. The position of the body-designing engineer is assuming greater prominence. The automotive engineer must have experience and technique, but the successful body designer must have both of these qualifications and at the same time be a true artist.

Mr. Johnson's paper brings out rather forcefully the fact that often bodies are not designed for the comfort of the passengers. The body designer necessarily meets rather a difficult proposition in that respect. There is always a certain competition between comfort and style.

There is no doubt that the chassis engineer and the body designer must work very closely together. Many of the body troubles in the past can be attributed to the chassis design. There is some question, however, as to just how rigid the chassis frame should be and how rigid the body sills or body frames should be; whether the chassis frame can take all the strain, so as to allow us to build a body with very light sills, or whether the body should be entirely self-supporting.

CAN AUTOMOBILE BODY WEIGHT BE REDUCED?

BY CHARLES A. HEERGEIST

AUTOMOBILE body building derives its origin from carriage body building, which was highly developed before automobiles were thought of. The introduction of automobile bodies fitted to a metal frame changed body builders' rules and calculations.

The influence of the metal frame is discussed briefly and the limiting sizes of body members are considered also. According to the ideas expressed, the weight of bodies can be reduced if the metal frame is designed so as to support the weight of the passengers and the body. The dead-weight also can be reduced if the frame is built in proportion to the amount of weight carried, the number of passengers and the style of bodies being considered. But in the construction of enclosed bodies, as in sedans, coaches and broughams, very little weight can be saved if stability, durability and lasting quality are to be retained. [Printed in the March, 1921, issue of THE JOURNAL]

THE DISCUSSION

GORDON BROWN:—Has any work been done with laminated woods; that is, using thin woods and binding them together with condensation products, such as condensite and bakelite?

CHAIRMAN W. G. WALL:—Do you refer to the cover for the body itself?

MR. BROWN:—Yes, to the wooden panels, to reduce their weight.

A. P. CARDWELL:—So far as I know, no one is building a body from laminated wood panels. The question has, however, been discussed a great deal. I think some panels have been built experimentally.

A MEMBER:—My company has spent about $10,000 in experimental work, largely with fiber wood products. An expert engineer in that particular line was not very successful and I was interested in knowing how the product failed. The hardest part of it was to get fabrication that would be reliable. We specified plywood for roofs. The company which was working on that particular line required a long time to get the manufacturing facilities up to the point where they could fabricate plywood and make it reliable. We found the same trouble in our experiments with plywood for the body. In fact, I think that plywood, so far as quantity production is concerned, has not yet been developed in the manufacturing process to the practical point where we can use it in bodies.

MR. BROWN:—In what respect did the product prove unreliable?

A MEMBER:—For one instance, the laminations did not knit together. The particular plywood that we used was supposed to be waterproof; waterproofed glue was used in making the laminations, but it was not waterproof, on actual factory test. Up to the time that we made our specifications, they had been brought up only to the production of comparatively small surfaces. They failed, I think, in trying to make large spreading panels. The experiment which we made with the body, which was very expensive, showed that plywood was not at all suitable. The panels were wavy and a proper surface could not be obtained on them because the fabrication was so imperfect. I understand that similar experiments have been conducted in many different automobile or body plants, but I have never come in touch with anyone who has been conducting those experiments.

LEON OTTINGER:—Regarding plywoods, certain waterproof glues are being made by the Casein Co. of America, which has a laboratory and is glad to help out the automobile trade in regard to any experimenting along the line that was just mentioned. I know that the framework of a body, made of laminated wood and waterproof glue, is being produced now in New York City, and that it has been successful. The body is covered entirely with aluminum, but the framework is all made of plywood and waterproof glue. It is claimed that in the ordinary runabout body about 65 lb. of weight is saved and that the strength is considerably greater than that of any bodies that have been built.

A MEMBER:—Is it a casein glue?

MR. OTTINGER:—Yes.

A MEMBER:—In its experiments our chemical laboratory found that the albumen glue is very much more waterproof than casein. That is what we specified. Our experiments were conducted with albumen glue; that is, blood glue.

CHAIRMAN WALL:—Laminated wood sills are certainly a good possibility.

G. H. WOODFIELD:—I had some experience with the use of haskelite roofs on sedans. This woodwork was supposed to be glued together with albumen glue, or glue made from blood. We put it through some tests. We boiled that wood for 2 or 3 days and could not boil those pieces apart; so, as our laboratory tests showed up very well, we thought we could go ahead and use it with safety. We used it on these sedans. The samples we got were fairly good but, when we got into production, it seems that they did something in preparing these panels that removed part of the softer fibers of the wood and made it porous. We could not obtain a surface on them or clean them up so that they would be smooth. Of course that made them objectionable on account of the time required to treat them with filler, rough-stuff them and paint them. We used them, however, but they developed a fine network of cracks all over and we discontinued their use because they were not satisfactory.

A. R. HOPKINS:—We have used a number of laminated roofs and find that our greatest difficulty is in the preparation of the wood paint. We find cracks developing along the joints in the wood. To date, we have no data on the proper preparation of the wood, the preliminary process that the wood must be put through to have it take rough-stuff and the necessary coating to bring about a smooth surface. We have put the roofs through the usual paint operations that we use for a steel surface but, in a number of cases, we found it necessary to scrim the entire roof to get a smooth clear paint jelly. What is the proper process to put these laminated roofs through to secure a smooth surface for the painting?

E. L. BARE:—That trouble has been experienced by several others. We found that medium-grade muslin which covers the entire roof stands up under almost all conditions and is satisfactory in that respect.

E. J. CONNOLLY:—So far as treating the wood is concerned, we have experienced much trouble with plywood for roofs, on account of cracking and not being able to paint it without waves. With this laminated stock for panels and the like, the greatest trouble has been to keep the panels from waving when going through the rubbing-deck operation. The differences in humidity cause the panels to wave more or less. There is no solution, to my knowledge, so far as body panels are concerned, because the same humidity does not exist in the factory while the different operations are being performed.

VICTOR PRESTON:—I think Mr. Heergeist's paper protected the body builders to some extent in regard to why they are not making lighter bodies today. Vehicle bodies have been built for a considerably longer period than automobiles, which accounts for the fact that recent body construction has not shown any marked degree of building lighter bodies, that point having been reached prior to the use of bodies in connection with automobiles. I think we must look for an entirely different method of body construction than that in use today if we expect to build a body much lighter and still maintain the strength and endurance required. At the Olympia Show, in London, there was on exhibition a body constructed with a framework of light steel tubing covered with aluminum panels; the manufacturer of it claimed to have reduced the weight to 50 per cent of the usual body construction, while still maintaining the strength.

In reference to plywoods and the like, during the period of making airplane parts for the Government, it was our duty to test thoroughly each batch of plywood received. So far as the practicability of waterproof glue goes, we were satisfied that it would meet the requirements; but one of the reasons that we avoid the use of plywood for body panels is the extra expense in painting them, in both time and material, over that of a metal. Plants producing large quantities of bodies are striving for as low a producing cost as possible, in addition to seeking lightness of body.

A number of car builders depend upon the body to some extent to support the chassis frame, which in my

opinion is not practicable. I have wondered as to the possibility of mounting a body on the chassis with a three-point bearing, or in such a manner as to allow the chassis frame to twist without affecting the body.

CHAIRMAN WALL:—There is no doubt that the airplane builder and designer can learn much from the body designer; there are probably a few things that the body designer can learn from the designer of airplanes. The whole basis of body construction, as it is now, depends greatly upon having the chassis frame sufficiently rigid.

F. E. MOSKOVICS:—The building of a body on an automobile chassis is a combination of ancient and modern art to about the last degree. The art of coach-building is some 400 years old; the chassis building art is young. Is it not, after all, a problem of whether we put the structural strength into the body or into the chassis? In 1896 I was working at the Daimler factory in Unter Turkheim, which is now in France. We would build a car and then some one would drive it to Paris. The chassis was designed to carry the calculated load, and it had all the strength and all the rigidity necessary to carry five passengers. We would drive to Paris and go to Kellner, Mühlbacher, Rothschild, or some other body builder, who would build on the chassis a body that also was designed structurally to carry five passengers. A man backed by 400 years of precedents in building carriage bodies is slow to accept instruction. We would give him instructions not to interfere with the spring action, the steering-wheel and the gearshift and the brake levers; then he would build the body with no mechanical cooperation between the chassis and the body engineer.

Someone suggested that if this body were built out 4 or 5 in. the passengers could be put in at the side instead of at the rear. As I see it, that was the only point of contact between the coach builder and the chassis builder up to about 4 or 5 years ago, and it is the only real structural development I have seen in body design before the advent of the very deep thin-section frames, in the case of which practically all the strains of the actual road shocks and twists are carried by the frame.

The body of one well-known car is made in three sections without any sill. The actual floor-board height above the frame is less than $\frac{3}{4}$ in. Each of the sections is bolted on the frame separately. In addition to being bolted to the frame, the rear section has an angle-iron which is bolted again with the idea of having it carry the top strains. The body is made entirely of aluminum, the only purpose of the wood used being to provide fastening bases for the aluminum panels and the upholstery. It is a very light construction and the job is very easily handled in a shop.

L. C. HILL:—Before attacking any problem of weight reduction in passenger-car bodies, it is necessary to make a careful analysis of the detail weights which constitute the total weight of a particular type. These can be grouped into three classes

(1) Parts essential to the structure, whose weight cannot be reduced materially
(2) Parts whose weight might be decreased, but at a considerable expense
(3) Parts which may be of lighter design, made of lighter material, or discarded entirely

It is the last class which deserves the study of the designer and, unfortunately, it appears to be the one holding the least promise. It must be understood that I am referring to only the particular type of body structure now in universal use. Radical designs must be resorted to if much decrease in weight is expected in the first two classes. There are details such as windshields, window glass, floor-boards and upholstery in these classes. They constitute a group which is essential and yet it is difficult to reduce their weight.

The use of airplane materials and practices in body construction has been a disappointment to many body men who were engaged in the airplane field during the war. There is a definite reason for this failure. The airplane is never expected to stand the abuse given the average car body and still maintain a high finish. It is carefully groomed by an able corps of mechanics and properly maintained at all times. Contrast this with the neglect accorded the average automobile; and yet the owner demands excellent finish and sturdy construction.

STYLE IN AUTOMOBILE BODIES

BY GEORGE J. MERCER

IT is not difficult to forecast the immediate future of the trend in automobile body models for quantity production, since quantity business necessitates a design that will please the majority and is a compromise between the old and the new. The design of an automobile body is one of the best advertising features of the car. Several factors contribute to make body changes practicable. The two preceding statements are elaborated.

The number of different body models that will prevail during the coming season is less than in past years; it includes the five-passenger touring car, the two-passenger runabout, the five-passenger sedan and the four-passenger coupe. The seven-passenger touring car and the seven-passenger sedan will be made in limited numbers.

These prevailing body types are commented upon in some detail, with special reference to style, the thought then passing to body lines that will prevail and the method of their development; the latter being illustrated by a diagram.

Minor and general considerations are discussed at some length. [Printed in the February, 1921, issue of THE JOURNAL]

THE DISCUSSION

GEORGE J. MERCER:—I understand that laminated wood is being used to form the framing of bodies and that the metal encases it. If this is practicable, and I see no reason why it is not, I think that it would be one move that would tend to produce a lighter body; also, it would eliminate some of the work necessary in framing. Those laminated parts could be made over a form that would give practically the entire contour of the body and the frame covering. It would allow some saving both in weight and in money. I do not know that this has been carried forward to any extent, but I understand that it is being tried out.

W. S. EATON:—There will be some demand for certain kinds of suburban cars, but I think the four styles

mentioned by Mr. Mercer cover the greater part of production.

CHAIRMAN W. G. WALL:—We are all striving to make automobile bodies appear low. One of the many ways of doing this is to put the brackets which hold the body 3 or 4 in. down on the frame and to make the sills vertical instead of horizontal. This makes the body appear lower, adds some rigidty to the body and reduces the weight.

H. J. WARREN:—Regarding Mr. Mercer's paper, I think the coupe and the sedan constitute little fine details. The whole tendency of the times in automobile designing is to refine details. We must have better workmanship. We must have trained mechanics. Our general results are all right, but we must require the shop workmen and factory foremen to turn out the sort of work that is wanted. Our whole trouble is in not being able to get the work done the way we would like to have it done; the way in which we designed it.

G. C. BAKER:—I come from a farming locality. In connection with the discussion about laminated panels, we have adopted a roof construction that I think has done away with all our trouble along that line. Being farmers, we naturally turned to poultry netting, as we call it. We have covered the bows supporting the roof with that, then with a layer of wadding, and then with waterproof material. We tried this as an experiment a number of years ago and found that we had no further trouble with roofs. It also eliminates the trouble with paint which some have experienced.

Mr. Mercer brought out one point on eliminating weight. He said that raising the belt moldings 2 in. has done away with a considerable number of square inches of glass. That, together with keeping the bodies low, does away with perhaps as great a percentage of weight as can be done away with in any part of the body. What success has been experienced with laminated wood as floor-board material, using a section perhaps $\frac{3}{8}$ or $\frac{1}{2}$ in. thick instead of the $\frac{3}{4}$-in. ash, or the material that most of us are using at present?

GEORGE W. KERR:—There seems to be an idea that laminated wood is a new thing. As long ago as 1885 I worked as a body-maker in Brewster's shop on Broadway, New York City, where the roofs were made of laminated wood. They made it themselves. At that time it was a long-advertised material for carriage roofs and for wagon side-panels. A company in New Jersey supplied it in any desired quantity. Dann Bros., in New Haven, Conn., at about the same time and I think continuously since then, have offered laminated wood glued up with waterproofed glue for roofs and side-panels. That was at least 25 years ago. They also used a casein glue. In 1888 I was draftsman and designer for the New Haven Carriage Co. One of the first problems that was assigned me was to find some way by which they could retrieve a few hundred phaeton bodies on which they had made the experiment of using laminated wood for the side quarters and which had appeared all right until they got on the varnish coats and were nearly ready to finish, when the surface of the wood was found to be full of fine cracks. Laminated wood never proved to be a cure for the troubles of tops or wagon panels. The wood is sawed around the log, then unfolded and used in a flat condition; this causes a rupture of the fibers of the wood, so that it is full of fine, almost invisible cracks.

In 1903 all of the Winton cars were made with mudguards of laminated wood, and so were the seat panels, both front and rear, and the doors. In 1904 the organization with which I was identified at that time made a contract with the same people who furnished the Winton to supply us with laminated panels for seats. We went through part of the season with seats made of laminated wood, but found we had to abandon it on account of its inherent disadvantages and go into the building of steel bodies. We were very early in the construction of steel bodies. I do not expect any revolutoin in the automobile body business resulting from the use of laminated wood.

As to Mr. Mercer's remarks about using laminated wood in the framework, I took that matter up with representatives of the plywood manufacturers and found that the price per square foot would be so very much greater than the price of ordinary wood that it would be absolutely prohibitive in production work to think of using plywood in place of planks.

The matter of the change of body design from time to time is really our life interest. There always is a style coming in, a style present and a style going out. It is always difficult to form a correct judgment on when to make a change and what change to make that can be coined into money. An expert on body design cannot tell by looking at a job whether it will sell or not.

The body engineer in an automobile plant is in a peculiar position; necessarily, it is subordinate to that of the chief engineer and other officials. He may conceive a design, execute it on paper and it may be the best design in the world; however, there are others who pass judgment on it who are probably very much less qualified to do so than the designer, but who have the power and the position to condemn and cast aside. Each body engineer has hanging over him the fact that his best work may not be recognized by those who are superior to him in position in the organization. The body designer must recognize the fact that in the very nature of the industry and art of body designing, he is subordinate and secondary to the chief and the chassis engineers. The mechanical engineers who designed the chassis for many years paid very little attention to the requirements of the body or to the ideas of the body designers. The latter were given a chassis of an arbitrary length and width, and had the problem of putting upon that chassis a good-looking body that would stand up. In many cases the impossible was given to them; the requirements could not be met. But time has smoothed that out considerably and the standard chassis now have dimensions which make it feasible to put on good bodies.

Regarding the stiffness of the frame which Mr. Moskovics mentioned, that frame is very stiff vertically. What provision is there in that type of frame to take care of twisting strains resulting from the irregularities of the road? The most vital problem that the body engineer has to fight is twisting strain on the body, rather than bending strain. Twisting strain is the main disintegrating force. The introduction of a chassis having the engine on three-point support, without any equivalent means of strengthening the frame against twist, results in a condition on many chassis that makes it absolutely impossible to build a sound body or one that will stand up.

On carriage bodies we had no trouble from twisting strains because there was always about the same amount of wood and metal and strength crosswise of the body that there was lengthwise. If a coach body was picked up on one corner, it would not twist 1/16 in. The springs absorbed all the road movement. In an automobile the springs absorb very little of the road movement in the case of three-point engine support; the advertising feature of the three-point-support chassis is that it does not

strain the engine. The chassis moves and allows the engine to stand still. The body is fastened to the chassis and it must twist as much as the frame does; as a consequence, everything tears to pieces. I believe body engineers ought to think, talk and fight against this, and make the chassis engineers realize that stiffness of the crankcase is the greatest factor they can use to stiffen a frame against twisting strains. There are many good examples of four-point-support engines that do not bind their crankshafts.

F. E. MOSKOVICS:—Relative to the twisting strains Mr. Kerr describes, an examination of the frame in question will show that no particular attempt is made to stiffen against them. We depend upon those strains being absorbed in a broad flexibility of the back. At the forward or cowl end there are two very rigid cross-members, one of which takes the drive of the car and the other of which supports the engine. These protect the car very effectively at that point against the twists. Out of some 16,000 cars now in existence with this construction, we have never heard of a body even being structurally loosened, much less destroyed by any of the road strains

to which it is subject, through design. I believe that after all this is the best answer.

L. C. HILL:—One thing should be emphasized in connection with Mr. Forbes' paper. If there ever was an opportunity for the body engineer to make his influence felt in this industry, it is today when people cease to buy automobiles and our salesmen try to sell them. This is the time for the body engineer to show the public something better and more comfortable. The foreigners have some rather peculiar lines and curves in their body design and many of us criticize their work, but those who have had the experience of riding in an English or French-built body, have ridden in something that is comfortable. It is very important now for the body engineer to begin to use his influence and sell his management on putting in refinements in car design that will lead to comfort and appeal to the vanity of the people who buy automobiles. The body designers will not need to sell the public on innovations if they standardize on comfortable designs and adhere to them, because these designs will appeal to the public without requiring sales talk.

THE BODY ENGINEER AND HIS RELATION TO THE AUTOMOTIVE INDUSTRY

BY KINGSTON FORBES

THE field of body engineering is broader than it is ordinarily considered to be; the author's intention is to bring to the attention of the automotive industry the breadth and scope of body engineering and outline the way this side of the industry can be considered and developed.

After describing the body engineer's position, the author then discusses at some length the conflict between art and economy in this connection. He classifies a body-engineering department under the six main divisions of body construction, open and closed; sheet metal, body metal, fenders, hood, radiators and the like; trimming; top building; general hardware; painting and enameling, and comments upon each. Following this he elaborates the reasons for need of attention to details in body designing and mentions the opportunity there is at present for bringing the materials used in body construction to definite standards. [Printed in the April, 1921, issue of THE JOURNAL]

THE DISCUSSION

DAVID BEECROFT:—The attendance at this first meeting devoted entirely to the subject of automobile bodies, being over 100 persons, indicates the very great interest there is in automobile-body design. When talking of the matter of standardization with the Chairman whom we appointed from the Standards work for this year, it was decided that we should have a Body Standards Division. In the general scheme of organization the committee will be very representative.

Reverting to Mr. Hill's remarks with regard to the European body situation, at the Olympia show, in London, we received much criticism on our open-body designs. This criticism did not include our enclosed designs. Two years ago, when visiting several of the factories in France, we had similar criticisms. This

past fall an English builder brought one of his automobiles to this country to try it out on our roads before going into quantity production. He brought his chauffeur with him and drove the car 4000 or 5000 miles. We sat in the back seat. The car had no foot rest and we did not need one. One trip was about 238 miles. That was an answer to the criticism the English have launched at us, that we sit on our bodies, whereas they sit in the bodies they make.

Two years ago the Darracq Co. was drawing some very direct comparisons with our practice in the upholstery line. I have since talked those over with some of our companies and it seems that production has stood in the way. When we ask why our automobile upholstery cannot be so arranged as to ease and hold the human body in the same way that the European upholstery does, the answer is that the Darracq and the De Lage companies have gone into a very thorough study of the human anatomy. They studied the origin of the tendons, their points of attachment and relationship; they went into a very extensive analysis of muscular movements, the positions of muscular repose and the like. All these were factors that entered into the arrangement of the upholstery and the general design. We ought to make the car as comfortable as possible, especially the rear seat. The owner and his family usually ride in the rear seat; not only do they take the wind and the bumps but all the other inconveniences. The chauffeur sits in the front seat, well hidden behind the windshield and occupying the best riding portion of the car; and now he is being protected by wings and other little devices on the windshield. We want to popularize the use of the car; so, let us make it a matter of comfort. Beginning in 1914, when we refitted our factories on a production basis, the whole problem was production. We have had in the last

few months a little opportunity to think of other things besides production, and I believe that we can accomplish something in the line of improvement.

CHAIRMAN W. G. WALL:—The point has always been made that American-built cars used in the United States had to run over such rough roads in years gone by that one could not be comfortable in any of them. Then it was not a matter of such extreme importance but, with our present road improvements, there is no doubt much truth in what Mr. Beecroft has just said.

L. L. WILLIAMS:—Body engineers have from time to time had occasion to look for certain body-engineering standards which they find are not available in the S.A.E. HANDBOOK. This applies to specifications for lumber, aluminum, sheet steel, hair, cotton fabric and other body-building materials. It seems to me there is a great need to issue, for the benefit of body engineers, something stable which we can use as a standard when we talk with these manufacturers who have been using their own judgment as to selling us what they chose and what their selling organization has said was the right thing for us to use. I think the Society ought to specify something that body engineers want to enable them to check against what the manufacturers want. Let us get some real engineering into body designing and actually set down something that we can go by. For instance, let us find out the tensile strength of cotton and other fabric for upholstery purposes and determine how long it can be expected to stand up. That is one way in which we can put this thing up to the manufacturers and make them realize that we have specific requirements. The same thing applies to sheet steel. We ought to know what it will actually stand, what the ductile quality of a piece of metal is. There are many good men here who have the information, but they seem timid and afraid to stand up here and make definite statements. They ought to stand up and make statements of fact and call everything by its right name, so that we can get body engineering on a basis equal to that of chassis engineering.

G. C. BAKER:—Perhaps the body engineer or designer is somewhat at fault himself. We have a Society of Automotive Engineers, and I think we have been a little slow about getting into it and pulling together. I joined the Society some time ago in the hope that the body engineers would get together on bodies in the same way that the chassis engineers have gotten together. The thing for us body engineers to do is to hoe our own row and not find fault with what the chassis engineer has put up to us. One of the speakers brought out the point that the engineer has suspended the engine on a three-point support, so that the engine would not be strained, and regretted the fact that this puts it up to the body designer to mount the body so that it will withstand the road jar. As body engineers we should take up our end of it and suspend the body on three points or in some different way if necessary. One speaker mentioned the fact that some method has been tried out of supporting a body so that it will swing free on a frame. These little points lead me to believe that perhaps we, as body engineers, have been as much to blame as some of the people who have put it up to us; so, let us pull together.

E. J. CONNOLLY:—When was the all-steel body first designed?

GEORGE E. GODDARD:—I cannot tell exactly. My first introduction to it was with Dodge Bros. Their first all-steel body was then in use. The first ones used in quantity production that I knew anything about were made by this company.

GEORGE W. KERR:—The first all-metal body that I ever saw was made about 1902. There were no trimming strips on the body. The trimming was all made so that it clinched under channel-iron frames.

SCHOOLS OF BODY DRAFTSMANSHIP

The principal thing that I wished to bring up in taking part in this meeting, is to make a plea for the establishment or re-establishment of the technical school of body draftsmanship. The Carriage Builders' National Association established a technical school in New York fully 25 years ago and operated it until the automobile superseded the carriage. For a brief time it was supported in some degree by this Society and its predecessor, but it was abandoned. It ought to be reinstated. There should be such a school available at a central point somewhere in the United States, where body design and body draftsmanship can be taught and developed.

In the old days the instruction in body draftsmanship was too much along an individual line. That was all right so long as it applied to carriages; when the carriage draftsmen began to go into the automobile shops, there was such a divergence in their methods from the standard methods in vogue in the drafting-rooms that it was difficult for them to become recognized as regular draftsmen. In almost every case they had to spend more or less time learning the technique of mechanical draftsmanship, so that their drawings, when turned over to the pattern-room and to the engineering departments, would be intelligible to the pattern-makers and the engineers. The line of instruction in the technical school I recommend should be designed to bring body drafting more into line with regular mechanical drafting, so that this trouble can be avoided. We have had to teach almost every body draftsman how to make mechanical drawings. There is a very essential difference between body drafting and regular engineering drafting. In almost every case the straight edge and compass will fill all requirements in mechanical drafting, but the essential basis of art in body drafting is free-hand lines that are not capable of being made with a straight edge or a compass. I wish to start a movement to get a technical school established at some central point, where this work, so worthily and so faithfully carried on by the Carriage Builders' National Association, can be carried on by the automotive industry.

CHAIRMAN WALL:—There is a great need of instruction of this kind. Could any of the present engineering technical schools be interested in the starting of such a department? Would that answer as well and could we get them to take sufficient interest to install some such course?

H. J. WARREN:—I studied in a carriage builders school some 35 years ago in New York, but when I came to build automobiles I had to learn mechanical drawing and engineering in addition. Even that was not sufficient. I have attended the two schools combined and even now find something lacking in my own knowledge and experience. A new school must be established. In the kind of school we need to have established, carriage drafting, designing, engineering, foundry practice, die-working and mechanical drawing must be taught. To establish that sort of a school we must find a principal who has been through such a school. Where can we find a man of that type who has been all through those various subjects? The suggestion is made, but how can it be carried out?

In the designing of cars the chassis engineers have ignored the body engineers completely. They have fur-

nished us with handicaps as severe as any architects could have encountered. We have made a few successes, but we have had a hard fight. When the chassis engineers begin to cooperate with us in building chassis, we will begin to see results. To produce a set of dies like the ones shown here requires a fortune. It cannot be done except in quantity production. How are small producers going to come in? They cannot do it; they have neither the time nor the money. When the chassis engineers accept the body engineers on an equal footing and allow us to work with them, we will get results. That ought to be the result of this meeting.

CHAIRMAN WALL:—The kind of discussion we have had is just what we need to assist in accomplishing results. There is no reason why all the body designers and builders should not work through the Society of Automotive Engineers.

S. J. HOWELL:—In regard to the question of establishing a body engineering school in a college, I am from a scientific school. We have what is termed the automotive engineering course. Our work in that line is looked down upon by the university; it is considered as being too specialized. The idea of the college is to give a course that will enable one to tackle the problems of engineering, but not to give the engineering problems themselves. On that account it seems to me that the scientific schools would not be willing to allow the establishment of a body-engineering course. They seem to think all the work should be entirely theoretical. If the body designers say that they want men trained in this line, the colleges might reconsider and turn out men who have some practical and general ideas of automobile engineering.

G. H. WOODFIELD:—I have experienced the same condition. I went through a school in New York City. The most successful designs I have produced have been those in which the chief engineer met me half way.

COOPERATION PRECEDENTS

C. S. RICKER:—One subject ought to be emphasized to body engineers who are not familiar with the work the chassis engineer has accomplished through the medium of this Society and the cooperation of its Sections. For example, in regard to the engine-starter and electric lights on the automobile, about 8 years ago there was just about as much cooperation between the men who were trying to find their way into the electrical equipment business and the chassis engineer, as body engineers seem to find with the average chassis engineer of today, although the two latter classes have been in contact much longer. The former two have come very close together and solved a problem that in many ways was equally difficult, if not more so, because the electrical men knew practically nothing about their own problem of handling the low-voltage electric current that was demanded on the automobile. We had in that instance a case of cooperation that has led to the present successful development in electric lighting for motor cars.

Another case of the same kind of cooperation is to be found now between the fuel men and the chassis engineer. It would be practically impossible to make a car perform properly if the chassis engineer did not concede something to the carbureter man and if he, in turn, did not give something to the chassis man to obtain an operable utility for public use. In the case of the body engineer, I think he will find that he can get close cooperation from the manufacturer. Many of the engineers who have appreciated the body-builders' problem are designing deep chassis frames now. On at least 10 cars, within the

last 2 years, the depth of the chassis frames has been increased from 1 to 3 in. to provide a more adequate support for the body. Again, the chassis engineer has been widening the frame and locating the springs beneath it, so that the channels would not twist with the spring action, thus providing a solid foundation upon which to place the body. In the support of the body the chassis engineer must have a kick-up in the frame at the rear end, to allow for spring action and provide the easy riding qualities that are demanded by the public. The cushions alone are not sufficient for this purpose. The carrying of a body sill over the frame kick-up also weakens the back end of the body. Efforts therefore were made to avoid these difficulties. For example, I have seen one frame on which the sills are absolutely straight, run along the side of the kick-up and are supported on brackets attached to the frame side-rail. Working this problem out in another way also helped the body engineer. This sill construction was made necessary by the manufacturing methods in the plant where I saw it. They did all their own painting and carried all the bodies through the ovens on flat chain conveyors. They also flowed all the color, prime and varnish, over their bodies. They found that with the kick-up it was difficult to handle the body on conveyor mechanisms without special supports and that was one of the chief reasons why they went to a straight flat sill the entire length of the body.

M. W. GAFFNEY:—I have had some experience within the past year in body designing and mechanical drafting. I find no difficulty whatever in breaking in good draftsmen for body drawing. I am willing to instruct these young men and they learn very quickly. I see no reason why we should be worried about that. A man with brains ought to be able to take up such work quickly. I see no reason for establishing a school. Such a school was all right in its day, but it has outlived its usefulness.

MR. GODDARD:—In one case where we had 23 different types of body, the drafting was a large problem. We subdivided it. The full-size draft from which the body was made was handled in a separate drafting department. It had its own sample body shop in which to make samples and test out the drafts before turning them over to the production department. We also had another division of the body-drafting department which took care of all hardware and such units as folding seats, foot-rails, robe-rails, hinges and locks. That class of work can be handled by mechanical draftsmen very well. The mechanical drafting division, as it might be called, also took care of the rear fenders, which are properly part of the body work. In our wood-frame construction we used the metal wheel-housing, which was handled by the mechanical drafting department, as well as the windshield and top parts such as sockets and the like. In order for them to work with the drafting department which made the full-sized drafts of the body itself, we found it necessary to make what we called a master layout. This was a special drawing or drawings showing the surfaces to which they had to work. For instance, we would take a portion of the body from the rear door-hinge pillar back to the center of the tonneau, working of course from the same points originally established on the master full-sized draft. We would lay out the shape, for instance, of the wheel-housing line; in other words, the line which the rear fender must fit up to. In that way the mechanical drafting division could work out their detailed drawings of the metal wheel-housings, seat panels and the fenders, such as a pattern-maker and the machine shop would use.

When the wheel-housings and fenders were assembled in the body, they fitted perfectly. The whole automobile body subject is a complex one, but it merely requires organization and subdivision. I have outlined the way the problem can be handled where bodies are designed and built in the same plant as the chassis. The idea of dividing the work and making the men specialists in their particular line of work may be helpful in the consideration of the problem.

MR. KERR:—Some remarks have been made that I dislike to have remain as the last word on the matter of a body-engineering school. The typical attitude of the mechanical engineer toward body designing and the body engineer was expressed; it is that anyone can do it. We who are regular body designers have spent our lives in acquiring something that the ordinary mechanical draftsman does not have an opportunity to work on. One of the qualifications for doing a poor job and a cheap job is ignorance of the subject. If we want to make the cheapest thing that can be made, the less we know about that thing the better, because our ignorance will lead us just a little way and there we will stop. The fact that all of the well-known carriage designers were drafted into the automobile business, after the regular automobile designers had come to realize that they were deficient on a certain subject, shows that the automobile-body draftsman and designer had something that they did not have. It is to perpetuate that something and carry it on, and make body draftsmanship a desirable thing to learn and a thing that will be continued, that I advocate the establishment of a school of body design. There is something in this body-designing business that the ordinary mechanical draftsman does not get in the schools through which he passes.

KINGSTON FORBES:—With reference to Mr. Mercer's remarks on laminated wood or wood-panel bodies, these require more time to make than the present style of wood-frame and metal-covered bodies. They require also equipment which takes up much space that would be out of the question in large-production manufacturing. This point is demonstrated by the manufacturer of the laminated wood roofs for closed bodies which require special equipment and large presses. It is also a harder and longer job to paint a wood body.

With reference to the ancient art of carriage building mentioned by Mr. Moskovics, very little of the 400 years of precedent is exemplified by the modern motor-car body. For example, the all-steel enamelled body is entirely a modern conception. In the last few years almost every form of construction that could be considered for an automobile body has been tried out and, so far, the solid-unit construction is found to be the most widely practicable and this is a combination of metal and wood. The real body development has been in the closed-car body, and this cannot be built up of different sections very conveniently. The closed car was primarily built for city use, but today the owner would be surprised if he could not drive his closed car 40 m.p.h. or over. If it rattles or creaks, he turns it over to the shop. To my mind the closed car of today is the real demonstration of every builder's progress in the art.

Mr. Hill brought out some important ideas in regard to the sacrifice of convenience and comfort in American cars. I think he takes rather an unfair advantage of the American body-engineer. In the first place, road conditions are entirely different in Europe from what they are in America. On the average road found in the United States, the passenger finds more comfort and ease in the straight sitting position of the American car than he could in the inclined position on some of the foreign cars. The average European car is in the cyclecar class; the larger cars are nearly all equipped with special bodies and no two of them are the same. Much of the hard-riding quality that can be justifiably complained of is caused by the rapid production methods in building, where the original shaped designs for the upholstery are lost sight of. There is one other point to be considered, which is that all-around riding comfort cannot be tested by taking show-room rides. Many cars which appear very luxurious in the show-room are not all desirable under average touring conditions.

A. F. JOHNSON:—In reference to the art and craft of vehicle body building, it is actually much more than 400 years old. In the World on Wheels, page 211, we read that

> As early as 1294 A.D., by an ordinance of Phillip the Fair, of France, for suppressing luxury, citizens' wives were forbidden the use of carriages, under heavy penalties; but this restriction was not long continued.

Further, quoting from Rondo, page 457,

> Up to the time of Charles VII, of France. in 1457 A.D., carriages were set directly upon the axles; but in that year Ladislas V, King of Hungary, gave a coach to the French Queen. This coach was much admired by the Court and by the people of Paris.

This presumably was because the coach was suspended on leather straps, as steel springs were then unknown.

NEED FOR RESEARCHES ON AUTOMOBILE PARTS

BY WILLIAM T. MAGRUDER

THE time has come when greater attention must be given to the smaller parts and the various appliances found on automotive machinery. Previously, investigations have been made by the research laboratories of a few companies manufacturing engines, carbureters and some other parts, but chiefly engines; by the laboratories of research corporations, including the Bureau of Standards and the Bureau of Mines; and by the engineering laboratories of colleges and technical schools.

The number and value of the researches that can be conducted and reported on from time to time by these agencies depend entirely upon the appropriations that they can obtain by act of legislation and upon the personnel of the staff that can be attracted by the opportunity to do this class of work. It would therefore seem to be to the interest of automotive engineers to advance the research work being done by Federal and State institutions, to see to it that adequate appropriations are made by Congress and the State legislatures and that those problems which need solution be attacked according to a guided program.

The author gives an account of engine tests made at Ohio State University, inclusive of considerable infor-

mation regarding the kind of research, methods, equipment and results. A further series of tests to determine power lost in transmission is described and commented upon in a similar manner, and mention is made of a series of tests which it is proposed to conduct to determine the power required to drive a car at different speeds. [Printed in the March, 1921, issue of THE JOURNAL]

A NEW PRINCIPLE OF ENGINE SUSPENSION

BY S. E. SLOCUM

AMONG new developments in the automotive field there is none which offers greater possibilities than the redesign of the engine suspension to eliminate vibration. The problem of overcoming vibration is related closely to the fuel problem, for vibration is responsible for a much greater loss of power and a consequent increase in fuel consumption than ordinarily is supposed. The common impression seems to be that, while vibration is undesirable, it absorbs but a small amount of power. This is not substantiated by actual facts.

Two instances are given to show what large power losses may result from vibration in certain cases. One is that of an automobile engine which had a badly balanced crankshaft; the other, an experiment with an electric motor mounted on a wooden table, the idea being to reproduce the condition of a machine mounted on the upper floor of an ordinary wooden building.

After a description of these two studies, the thought passes to other disastrous effects of excessive vibration and the consideration of critical speeds at which the most serious losses due to vibration occur.

The causes and types of vibration and the elimination of vibrations due to synchronism are discussed in considerable detail, followed by an illustration and account of one method of applying this principle to automotive apparatus. [Printed in the January, 1921, issue of THE JOURNAL]

A SUGGESTED RATING RULE FOR RACING CARS

BY H. M. CRANE

IN recent years automobile engines for racing purposes have been very generally rated in accordance with their piston displacement. The natural result has been to encourage the highest possible engine speeds to attain the greatest possible piston displacement per minute. Features of engine design that have been developed under this rule include enormous valve areas, usually obtained by a multiplicity of valves, huge inlet pipes and carbureters, extreme valve-timing and very light reciprocating parts, all of which are undesirable in commercial engines.

To encourage the design of engines of a type developing higher efficiency at lower engine speeds, the suggestion is made that a rule be formulated under which cars will be rated in accordance with the piston displacement per mile actually used by them. Such a rule would involve rear-wheel diameter and gear ratio, as well as the piston displacement of the engine. This would automatically allow the use of engines of varying size, provided the other elements were proportioned properly. [Printed in the February, 1921, issue of THE JOURNAL]

TORSIONAL STRENGTH OF MULTIPLE-SPLINED SHAFTS

BY C. W. SPICER

THE results of some tests recently completed are presented. No attempt is made to develop the theory involved. It is intended to describe only the actual tests, the conditions under which they were carried out and the results obtained.

Superficially, it would seem obvious that the torsional strength of a multiple-splined shaft is greater than that of a full round shaft having a diameter equal to the small diameter of the splined shaft. Data on this and related questions were sought experimentally. A series of tests was run on 15 carefully machined shafts. The dimensions shown are the actual ones of the test-pieces, there not being more than 0.0005-in. variation in any shaft from the diameters shown. Heat-treating was very carefully carried out, and each specimen carefully checked by Brinell instrument on the ends and by scleroscope throughout the length. The Brinell numbers were all between 220 and 235, and the extremes of scleroscope hardness were 38 and 43. The testing machine and a composite curve of test results are shown. [Printed in the February, 1921, issue of THE JOURNAL]

ECONOMY AND PERFORMANCE DEMANDS

BY J. G. VINCENT

STATING that economy and performance are diametrically opposed in that the greater the performance demanded the less the economy is likely to be, the author mentions that the gasoline bill of the average user is not the major portion of his expense and asserts that economy is determined very largely by the engine design, the chassis design and the tires. The subject of engine design is outlined and consideration is given to acceleration during periods of coasting.

Discussing briefly the chassis and the tires, attention is given to oil and tire economy, followed by statements regarding design from the viewpoint of service and performance as influenced by gear-ratios and gear-shifting. [Printed in this issue of THE JOURNAL]

CHASSIS DESIGN FOR FUEL ECONOMY

BY A. L. PUTNAM

AS the engine is the most important unit of a complete automobile chassis, it has had a major share of attention in its development and is far in advance of the rest of the machine as a result. Consequently, at least for the passenger-car engineer, improvements in the automobile as a road vehicle offer greater scope and reward than improvements in engines, particularly as all such improvements are reflected in direct proportion instead of being minimized by adverse operating conditions. The attitude has been common of not worrying about a fraction of 1 per cent loss here and there when such an enormous loss occurs at the exhaust pipe and radiator. Other varying and intermittent losses in the aggregate are not insignificant and, when multiplied by millions of cars, become millions of gallons of fuel and oil.

The author's aim is to call attention to some of these losses, with suggestions as to means and methods of correction. This includes a study of the effects of heavy greases, dragging brakes, relative motion of parts and tire sizes, all of which are discussed at some length. [Printed in the February, 1921, issue of THE JOURNAL]

THE DISCUSSION

CHAIRMAN H. M. CRANE:—My paper entitled A Suggested Rating Rule for Racing Cars[1], states all that I have to say on this subject. I hope the engineers in the automotive industry will do some thinking along those lines, for I believe they might in this way learn more by racing than they are apt to learn under the present rule.

This meeting was called primarily to bring out questions that have come up in our various conferences on fuel with the members of the petroleum industry. We have been under a constant fire from the other side, on the question of why we use so much gasoline. When I first began using gasoline, about 1898, the producers did not worry about how much we used; in fact, they worried about how little we used. However, they have put a strong burden of proof on the engineers in this industry to show why we should not reduce our consumption per passenger-mile and per ton-mile. The greatest and most spectacular gains in this direction can be made in engine design and in a most interesting line of work. On the other hand, we must not overlook the fact that those gains are simply in the production of power, and that we must show also that we are not using more power to accomplish results than is justified.

The petroleum industry has taken a certain point of view regarding the use of the small car, that I think deserves comment. The automobile is supplied to give service; if it is a truck, it must carry tonnage; if it is a passenger car, it must carry passengers. Part of the service in carrying passengers lies in the speed at which the passenger cars are operated and the comfort in which the passengers are transported. We have no right to overlook these facts. We are called upon to give the public comfort and speedy transportation, even if this uses somewhat more gasoline than slower or less comfortable transportation. For instance, I think we cannot ask the public to use open cars without tops or windshields, simply because they require less gasoline to drive than sedans or limousines. In that case, we would not be giving service to the public.

[1] See THE JOURNAL, February, 1921 p. 118.

I will speak of several points regarding chassis design to illustrate what I have in mind regarding the possibilities in that direction. We have been asked by the petroleum industry why we use such high-geared cars; why the public is given cars that can go everywhere, almost, on high gear. The public does want such cars, but is it not for the reason that gearshifting today is largely a matter of strength and acrobatics? We have made gearshifting so difficult that the use of the lower gears is confined to starting and times when progress cannot be made in any other way. Unfortunately, the design of the present type of engine is such that the very means we use to cut down its power, throttling, also reduces its economy. I was told of some very interesting tests that had been made to illustrate this fact. On a flat track a car would make the best mileage per gallon if opened up wide for a given distance, accelerated to a fairly high speed and then allowed to coast for a given distance with the engine shut off. That is a very clear illustration of what I mean. Theoretically, that should not be the case so far as the resistance of the car is concerned, because the resistance of a car to propulsion is not in the form of a straight-line curve, but goes up very rapidly with increase of speed; and, the higher the speed is, the more rapidly it goes up.

Another phase in which many of our smaller cars are deficient is the braking. The brakes are partially applied all the time, and no reasonable means is provided for the average owner to keep them properly adjusted so as to hold when he wants them to hold and yet not drag when that is not desired. Another feature, common in some of the cheaper cars, is the defects of gearbox and rear-axle design. These gearboxes and axles are designed in such a way that oil cannot be used for lubrication. Grease of a heavy character is required, for oil will escape so rapidly that the gearboxes rapidly become dry and the cost of operation with oil too great. In high-speed apparatus, such as the automobile rear-axle and gearbox, grease is a very poor lubricant. It also absorbs a large amount of power in operation. In other words, many probably had experience in the old days with cars whose gears could not be shifted on a cold morning and yet after running for a time could be shifted easily. That was partly due to the heat of the engine but, also because the churning of the grease produced heat and power was required to produce it.

I have sketched a few points that enter into the big problem of economy of service. I say "service," as against economy of operation, because economy of operation only goes part way. We must give the owner service and at the cheapest price. Part of the service, as I said, is in speed and comfort.

I am glad that Mr. Putnam put so much emphasis on the tire question. The tire companies have failed in their literature to begin to take advantage of the possibilities of the cord tire. They have recommended pressures that produce exactly the results Mr. Putnam has outlined. For obvious reasons the cord tire is a big improvement over the fabric tire in efficiency. The efficiency of any spring is the amount of energy that it will return, compared with the amount put into it. The fabric tire is inherently a shock-absorber, and that is the cause of its relatively great self-destruction; being a shock-

TABLE 1—PISTON DISPLACEMENT PER MILE PER POUND OF TOTAL CAR-WEIGHT AND PER POUND OF PASSENGER-WEIGHT

Column			1		2	3	4	5	6	7	8	9	10	11	12	13	14
Designation	Car — Type	No. of Cylinders	Bore, in.	Stroke, in.	Piston Displacement, cu. in.	Tire Size, in.	Tire Revolutions per Mile	Gear-Ratio on Direct Drive	Fuel Inspired, cu. in. per mile	Weight with Complete Equipment, Tanks Full, lb.	Number of Passengers	Total Weight with 150-lb. Passengers, lb.	Percentage of Passenger to Total Weight	Cubic Inches per Mile per Pound of Total Weight	Cubic Inches per Mile per Pound of Passenger-Weight	Assumed Mileage per Gallon	Col. 12 Divided by Col. 13
A	Ordinary	12	3	5	424.1	35	576.2	4.36 to 1	532,720	4,746	7	5,796	18.1	91.91	507.35	....	.....
B	Ordinary	8	3⅛	5⅛	314.4	35	576.2	5.07 to 1	459,324	4,035	7	5,085	20.6	90.33	437.45	10.0	43.74
C	Large	6	3½	5¼	303.1	33	611.2	4.33 to 1	401,385	3,690	7	4,740	22.2	84.68	382.27	....	.....
D	Small	6	3⅛	4¼	195.6	33	611.2	4.63 to 1	277,149	2.600	5	3,350	22.4	82.73	369.53	....	.....
E	Large	4	3¾	6¾	298.2	32	630.2	3.87 to 1	364,098	4 030	6	4,930	18.2	73.85	404.55	12.5	32.36
F	Small	4	3¼	5½	182.5	32	630.2	4.87 to 1	280,344	2.640	5	3,390	22.1	82.70	373.79	20.0	18.69
G	Motorcycle with Side-Car	2	3 5/16	3½	60.3	28	720.3	4.91 to 1	106,701	563	2	863	34.8	123.64	355.67	35.0	10.16

absorber, it absorbes energy and over-heats. The difficulties that Mr. Putnam outlined come from very plain causes. In the rear axle, especially, we have a heavy weight swung between two sets of springs and, unless it is damped in some way, it will acquire, under certain conditions, some very remarkable activities when the periods of the two sets of springs get into certain relation.

AUSTIN M. WOLF:—Mr. Crane's suggested rating rule for racing cars is a very meritorious one and it should result in increasing the efficiency of the car as a whole, in that everything else will be taken into consideration and receive as much attention as the engine receives today. We picture engines and nothing else when we think of racing cars, and neglect to a large extent the rest of the chassis. Limiting a car to a certain piston displacement will develop an engine that is good for only high and constant speed. This, as Mr. Crane says, is not the commercial engine we desire for automobile use.

I think that Mr. Crane's suggestion can be applied to advantage in our present-day production of cars, carrying the displacement to a weight basis, and while the figures I give are susceptible of various interpretations, they nevertheless bring out some interesting facts. What I propose to do is to consider the piston displacement per mile per pound of total weight of the loaded car and per pound of passenger-weight. I have divided the cubic inches of piston displacement per mile by two, in that the result would be the amount of charge that the four-cycle engine would draw in through the carbureter. The relative value of the figures remains the same nevertheless, and this figure could be used in determining the theoretical fuel consumption on a basis of air to fuel ratio.

Table 1 lists representative touring cars and also a motorcycle with a side-car. A summary is given of the cylinder size, the piston displacement in cubic inches, the tire size, the revolutions of the tire per mile, the gear-ratio, the cubic inches per mile inspired through the carbureter, the weight of the car ready for the road with complete equipment and the tanks full, the number of passengers, the total weight, the percentage of the passenger to the total weight, the cubic inches per mile per pound of total weight, and the cubic inches per mile per pound of passenger-weight.

It is interesting to note that, on a basis of total weight, the motorcycle consumes a greater number of cubic inches than any of the cars. However, due to the fact that the passenger load constitutes 35 per cent of the total weight, we find that the motorcycle obtains the best performance on a basis of cubic inches per pound of passenger-weight. This is an argument for reducing the weight of our cars. As Table 1 shows, the passenger load constitutes from 18 to 22 per cent of the total load.

The effect on the gear-ratio is very noticeable in the case of Car E. For its size this car consumes the smallest number of cubic inches per pound of total weight of any of the vehicles mentioned, and in the cubic inches per pound of passenger-weight it shows a very creditable figure. The table is, of course, based on the rated capacity of the manufacturer. Referring to Car E, there is no doubt that a seven-passenger model could be built that would weigh the same as the six-passenger type. In this event the cubic inches per pound of total weight would be 71.67, and the cubic inches per mile per pound of passenger-weight 346.75, which is the best figure of any under Column 12. The effect of a high gear-ratio is thus brought out, in line with the findings of Mr. Nelson in his paper on the Fuel Problem in Relation to Engineering Viewpoint.[2] The figures in Table 1 assume, of course, that the efficiency of the carbureter, engine, transmission, axle, tires and the like, is equal in all cases and that all losses are the same. This, however, is not the case and probably a factor which is the readiest criterion would be the miles per gallon of fuel consumed. There still would be some variables such as atmospheric conditions, road and wind resistance and kind of fuel. If we divide the figure that is obtained in Column 12 by the number of miles per gallon, we obtain another result that is very interesting. We assume that the vehicle obtains the number of miles per gallon of fuel given in Column 13. The results in Column 14 show what light-weight construction can do, as in the case of a motorcycle.

[2] See THE JOURNAL. February, 1921, p. 101.

W. P. KENNEDY:—I am presenting this communication on behalf of Col. A. J. Slade, who was in Europe during the war period as Chief of the Engineering Division of the Motor Transport Corps and, as a member of the International Armistice Commission, went into Germany to take over the German trucks. He was impressed while over there with the desirability of using light cars for courier service and, in collecting the German trucks, took advantage of this opportunity to send back three models of very light car which had been used by the Germans in courier service and which have since been in Baltimore. He recently communicated with the Engineering Section at the Motor Transport Depot, Camp Holabird, Baltimore, Md., asking what disposition had been made of these three machines and whether any progress was being made in taking advantage of them in the camps, in applying them to military service. The communication from W. T. Norton, chief of the engineering branch, Motor Transport Corps, is as follows:

> Relative to small German passenger cars, this section has at present three such cars; namely, a Mathias, a Benz and a Wanderer. The Wanderer car has been rebuilt and is in courier service between Camp Hola-bird, Md., and Washington, averaging 110 miles per day. The Mathias car is being rebuilt and probably will be put in the same service in the near future.

> The general idea of testing out these cars is to see if there is any possibility of doing away with the heavy motorcycle and side-car which has been used previously for mail courier service. The maintenance of the heavy motorcycle and side-car in this kind of service is excessive and the tests which we have conducted so far indicate that a car of the Wanderer type will be more economical to maintain and more reliable.

> In the event that cars of the Wanderer and the Mathias types test out successfully, it is believed that these vehicles should be Americanized. The track should be increased from 48 to 55 or 56 in. and the general design changed to make the various units more accessible. The present German designs are such that repair work on any of the units is very difficult, requiring considerable time and labor.

JOHN YOUNGER:—I did a good deal of work on splined shafts from 1913 to 1915 and embodied the results in a paper presented before the American Society of Mechanical Engineers.[3] This paper shows the effects of different heat-treatments on splined shafts, the effects of several alloy steels and also the effects of various diameters on the central portion of the shaft. I think it proves conclusively, as does Mr. Spicer, that the strength of the shaft with splined ends is the same as the calculated strength of the smallest diameter at the bottom of the spline. Reference is given in my paper, in connection with some of the tables, to part of C. E. Garrard's study of splined shafts made several years before. It seems to me that a bibliographical list of such papers should be compiled.

C. W. SPICER:—Attention should be called to the fact that the experiments reported on in my paper indicate that the strength of a splined shaft is even *less than* the strength of a full-round shaft of diameter equal to the smallest diameter of the spline. To be specific, the difference in this particular case amounts to an average of 18 per cent. This discrepancy is of sufficient importance to be taken into consideration when making careful calculations.

CHAIRMAN CRANE:—I do not know whether Mr. Spicer

[3]See *Transactions of the American Society of Mechanical Engineers,* vol. 39, p. 355.

has had an opportunity to go into the effect of repeated stress on splined shafts, but the tendency is distinctly to enhance the effect he has found on a straight torsional test, especially if the fillets in the corners of the splines are not amply great. We had a shaft break in torsion under those conditions. It looked like a perfectly good pie cut into segments, with cracks leading from the center to the corners of the splines. Of course, what happened was that the metal of the spline actually aided in overloading the already highly stressed metal on the surface of the round part of the shaft. I hope that, if Mr. Spicer has made equivalent tests on various sizes of squared shaft, he will give us the benefit of them at this or at some later date.

PROF. S. E. SLOCUM:—The main object of the type of suspension described in my paper is to relieve the chassis from the vibration ordinarily transmitted to it by the engine. It is not necessary, in this connection, to discuss what produces vibration of the engine, but only to consider the effect of vibration on the chassis. Whenever the speed of the engine falls into step with the natural frequency of vibration of the chassis or of the body, the vibration is greatly intensified; in other words, whenever we have synchronism between the engine and the chassis we have those excessive vibrations known as periods. If it were not for this synchronism between the engine and the chassis, the average person would scarcely know there is any such thing as vibration. Therefore, relieving the chassis of vibration is very largely a question of destroying synchronism between the engine and the chassis.

There are a number of distinct effects of vibration on the chassis. There is, of course, a considerable loss of power. We hope to have soon some experimental data that will show exactly how great that is. Vibration tends to produce fatigue of the material and, with the ordinary type of rigid engine-mounting, this matter has to be taken care of in designing the chassis. From the buyer's standpoint the greatest objection to vibration it its unpleasant effect on the passengers.

The principle underlying this new type of suspension consists in employing a three-point mounting of the engine, one of these three points being rigid and the other two being resilient. The effect is to permit a certain vibration of the engine within small limits, about any axis passing through this fixed point. The engine is insulated from the chassis in a sense, so far as vibration is concerned. It is free to vibrate with a very small amplitude, without transmitting that vibration to the chassis or to the body. By properly designing these resilient supports, we can make sure that the period of these resilient supports is different from the period of the engine and also from the natural periods of the chassis, and in that way we can destroy synchronism which is responsible for most of our vibration trouble.

There are many different ways in which this principle can be applied. In Fig. 1 of my paper the principle is applied by mounting the engine in a sub-frame or cradle, and suspending this cradle from the chassis with a three-point suspension, the rigid support in this case being directly under the transmission and the two resilient supports being at the forward end of the engine, one on each side. In this particular application, the two outer members shown in Fig. 1 represent the two rails of the chassis. The engine is mounted in the sub-frame, just within the two channels of the chassis. The rigid point in this case is placed directly under the transmission and consists of a ball-and-socket joint or its equivalent. The two resilient supports are placed at the forward end of

the engine. That gives a three-point support for the cradle. The engine can be mounted upon this cradle in any way that appears desirable. The point is that the engine, together with the cradle, is free to oscillate about any axis through the fixed point. The extent of the oscillation is controlled by designing the resilient supports so as to permit vibration of a very small amplitude, but also so that the supports will be very rigid as regards shock.

MR. WOLF:—Will Professor Slocum state why the rigid support of the suspension system he described is located under the transmission? Is there any particular reason?

PROFESSOR SLOCUM:—The idea is to minimize motion of the brake-lever or the gearshifting lever, but the whole suspension can be reversed just as well, and the fixed point placed in front and the springs in the rear; or any other combination that seems best for a particular engine is feasible. The thing is to adapt the principle to the engines as they are at present. The most practical, although not the ideal, way seems to be to mount them in a cradle as shown.

JOHN G. PERRIN:—I cannot say that we have much to learn from what I saw recently in Europe. We have heard much about the wonderful economy obtained there but, although perhaps we might find some modifications in the engines or cars, my conclusion is that there is nothing radical in that respect. They obtain the high economies we hear about with small cars, such as would not be adapted to use in this country unless we got over the idea of wanting to do everything on high-gear. The so-called small cars have about a 48-in. track. We found that absolutely unsuitable to American conditions, except in sections where the roads were very highly improved. The engines are practically not different from ours. They are using a great number of I-head engines, but there is still a greater number of L-head engines. They are improving in a number of detail that we have found advantageous, such as making the pockets in the combustion-chamber as small as possible and using a good lubricating system. Their carbureters have no wonderful or mysterious features that are not embodied in our own best carbureters. They obtain light weight by building small cars. We have done that, but have found it impracticable for the market. Their large cars attain no better fuel economy than our own best cars. For one thing, they use cars of higher gear-ratios. We have found such gear-ratios unsuitable for our purposes, because we want to do everything on high-gear. We all know that high gear-ratios promote fuel economy. Their connecting-rods are better than ours and they can maintain longer periods of driving on their direct drives, thereby getting better fuel economy.

In regard to advanced design, there was nothing very remarkable, except the Ricardo engine that is being produced now. It was used during the war in a number of tanks. Much is claimed for it in a number of ways. It has a very long piston, in two sections; one acts like an ordinary piston and the other as a guide for it. They claim elimination of all condensation of fuel in the crankcase, better lubrication and avoidance of much of the piston friction. I believe that insufficient attention is paid to the losses in piston friction. Designers try to reduce engine weight by using short connecting-rods and thereby add a great amount to the piston friction losses.

The British builders are paying much attention to the small cars, but I could not see that their market is suitable for them. Very small clearance is allowable on the English roads and they certainly can reduce weights a

great deal. A small engine will propel five people around very satisfactorily. Their small engines are rated at 11 or 12 hp. One very dominant reason for bringing the horsepower down and using the smaller sizes of engine is the tax of £1 per horsepower, which is of course a considerable burden to car owners.

Their mileage per gallon of fuel is based on a better grade of gasoline than we use ordinarily. It is similar to the grade of gasoline we were getting 4 or 5 years ago. Their gallon is the Imperial gallon, which is larger than our gallon; six of our gallons are needed to make five of theirs.

In their high-priced cars there is a tendency to incorporate a number of airplane-engine features, such as aluminum cylinders with steel inserted sleeves. I do not see that we have anything to learn from European practice. We are further along, I believe, in solving the fuel-economy problem and, judging from all I have heard here today and from what I know is going on around the country, we are certainly attempting reduction of weight much more actively and to better advantage.

LEE W. OLDFIELD:—While in France, after the armistice, I had occasion to use one of the Wanderer cars and also to make rather extensive tests with a Petit Peugeot car. Each of these cars has a four-cylinder engine of 60-mm. bore and 90-mm. stroke. The only detail of construction on the Wanderer car that is particularly interesting is that the transmission case is made of steel stampings.

With regard to economy and performance, the Petit Peugeot, which is a slightly smaller car, had a very much better performance than the German Wanderer car. I drove a Petit Peugeot from Paris to Clermont-Ferrand. On one particular stretch, a distance of about 70 miles, we made an average of 28 m.p.h. for about 2 hr. 18 min. with this little car. It rode very comfortably. The fuel consumption was at the rate of slightly less than 7 liters per 100 km., which works out very close to 35 miles per gal. There were no details of particular interest in the engine of either of these cars. They were both magneto-equipped and, generally speaking, of standard accepted design. The Wanderer had silent chains for the front-end drive and the Petit Peugeot had a set of fiber gears.

MR. OLDFIELD:—The Petit Peugeot behaved remarkably and will run astonishingly fast. It has direct drive on both second and third speeds. The car is very nearly as fast on second speed as it is on third; I should say there is not a difference of more than 10 m.p.h. One becomes nervous when driving wide-open in second speed, expecting a number of parts to come up into one's lap, but the car continues to go. The gear-ratio is about 7 to 1 on second and slightly better than 3½ to 1 on third speed, with about a 21-in. wheel. I believe the Wanderer car uses a 28-in. wheel. It did not ride or stay on the ground as well as the Petit Peugeot, although it is a car of 100-in. wheelbase, whereas the Petit Peugeot wheelbase does not exceed 60 in.

MR. MANLY:—What is the weight of the Peugeot car?

MR. OLDFIELD:—About 1300 lb., with the load.

CHAIRMAN CRANE:—That comparison of two small cars is very interesting, but I would like to have those present figure the ton-miles per gallon of the Petit Peugeot on the basis of 30 miles per gal. and 1300-lb. car weight. It is easily possible in this country, with cars having maximum acceleration, to do 30 ton-miles per gal. On the basis of 1300-lb. car weight, even allowing somewhat extra for two passengers, this car was not

doing much over 20 ton-miles per gal. and, after all, the ton-miles per gallon is the real solution as to economy in transportation. I speak of this particular case, in view of the fact that it represents ordinary road conditions, not an attempt to obtain maximum economy. There is a great difference whether we coast every grade we come to with the engine shut off, or leave the clutch in from the time we start until we stop. The 30 ton-miles per gal. performance can be and is being obtained in this country on high-acceleration cars, with the clutch engaged from start to stop, the engine throttle being set in the idling position and the accelerator being used during the run. That is very much more expensive in gasoline than under conditions where an attempt is made simply for economy and nothing else. I assume this run was made under absolutely similar conditions. I wanted to call attention to the fact that the economy, while actually high in figures, was not really high, especially for a car with limited comfort available.

T. C. MENGES:—I have operated one of the Petit Peugeot cars for several years. The average performance is about 35 miles per gal. on the country roads. The car weighs slightly more than 800 lb. and is a two-seater. It is not well adapted to our country roads. We shift gears even on paved streets. I do not think very well of it as a practical driving car.

MR. MANLY:—In connection with tests on tires, what are the figures as to the actual efficiency of the tires? We have, for example, a certain amount of power going into the tire and a certain amount of work delivered by the tire. What is the efficiency, both as a supporting mechanism and as a straight transmitting mechanism? A number of years ago some tests were made at Cornell University on bicycle tires, but I have not seen recent data of that kind in connection with automotive tires.

CHAIRMAN CRANE:—We produced some very interesting results of that kind, with a drum dynamometer. The rear wheels of the car were run on a pair of drums, the engine was operated and the power delivered at the rear wheels was measured. The results showed an extreme loss in the power delivered by the tires. In the case of one car tested under those conditions, it lost the difference between 45 and 36 hp. in the tires alone. That is a very high percentage of loss in power. Of course, that was in the days of fabric tires. We know that cord tires are very much better.

MR. MANLY:—The figures obtained in the bicycle-tire tests were very surprising as to the low efficiency of certain classes of tire. The efficiency seems to be almost exactly in inverse proportion to the thickness of the tire. The racing tires they were using on bicycles at that time were of high efficiency, compared with the double type of shoes on automobiles; and those tires showed very much better results, compared with solid tires. If we could get some recent data, I know of nothing that would be more interesting on this question than the general improvement of the economy of the tire. We talk about efficiency of the bearings and efficiency of various other parts, when, as a matter of fact, we actually are losing more power in the tires than in anything else in the transmission of the engine power to the rear-axle.

A. L. CLAYDEN:—Many tests of tires have been made at Yale University by Professor Lockwood. He read a paper[4] entitled Power Losses in Pneumatic Tires before the Pennsylvania Section about 4 years ago, in which he gave the results of a number of tests. I looked at some

[4]See TRANSACTIONS, vol. 12, part 1, p. 377.

of the figures a few weeks ago. They show the tire loss is in the neighborhood of one-third of the total. I understand that Professor Lockwood is now getting data together for presentation to the Society this year, and that he has been making these tests with the idea of showing the effect with different sizes of tire carrying the same load.

MR. MANLY:—As regards efficiency, in connection with the matter of tire-inflation pressure, I think these tests will show that the tire is much more efficient when highly inflated. Cars ride more easily when the tires are soft, but I think there will be a tremendous difference in the efficiency when the tire is highly inflated.

CHAIRMAN CRANE:—That is undoubtedly true, but it is also a matter of the efficiency of the casing. In other words, if a perfectly flexible casing could be produced, I think the tire efficiency would be practically the same, no matter what the inflation pressure inside the casing. The fabric tire casing was not flexible; it protested by overheating and blowing up when we did not keep it pumped up. That is the answer to the question as to where the power is being lost. In fact, the tire becomes hot, which indicates that gasoline is being burned to heat it. The only thing there is to heat the tire is the gasoline we burn in the engine. Unfortunately, this wastes gasoline and also wastes tires.

A MEMBER:—I can confirm the remarks made about Professor Lockwood's tests at Yale University. I have run a test recently in which the tires were operated on a drum. This gives a reflex action to the tire. It probably allows somewhat more power loss than would be normal on a flat surface. The tests we have run show that the power loss in a cord tire is 20 to 30 per cent; in a fabric tire it is somewhat higher than that.

W. E. WILLIAMS:—Mr. Putnam mentioned an idea that I think is worthy of serious consideration by the tire-building industry, namely, building a large tire with a thin wall, thus making the tire act in the place of springs to a large extent. In the past the making of a tire that would stand in service has so occupied the attention of the tire builders that this feature has been overlooked or little considered; but now that the cord tire allows the individual cords to move more or less independently and with a considerable cushion of rubber between, there is a possibility of making tires larger in diameter with thinner walls and for lower inflation pressure.

Regarding the task of shifting gears and the statement that the car driver prefers to drive in high-gear rather than bother to shift gears, a large amount of brain power has been spent on automatic gearshifting devices. The trouble is that when one goes through any sort of volition to shift gears, even simply to operate a small lever or button, that act causes as much trouble in volitional labor as is demanded to shift the gears actually. The solution of the difficulty lies in simplifying the movement of the present system of gearshifting.

J. A. ANGLADA:—Referring to Mr. Putnam's paper and to Mr. Williams' remarks relative to the elimination of springs and the substitution of pneumatic tires to do their work, with a five-passenger car we probably would use a tire of 12-in. cross-section. I saw a truck that was fitted with 12-in. pneumatic tires. One of the rear tires exploded when the truck was going about 15 m.p.h. One side of the rear went down and the truck turned over. I am inclined to believe that if we use tires of that size on passenger cars we might get the same result in the event of a blowout.

GORDON J. WATT:—Is there any definite and detailed

information regarding the French test? It seems to me that the results published in this country do not in any way give proper credit to the American cars. It seems that the French cars had expert handling, and that the American cars had no more than ordinary handling at best and possibly very poor handling. They are doing nothing more to save fuel in Europe at present, at least on the cars in use on the public roads, than is being done in this country. They are getting better mileage, but not better ton-mileage. I think that the publishing of the results of the French tests, without further data, is a bad thing for the American automotive industry and an investigation should be made to see whether those published results conform with the actual conditions of the test. I understand that the French cars have very high compression and everything in the way of special lubrication and the like to make the economy as good as possible.

O. A. MALYCHEVITCH:—The Petit Peugeot is a first-class car in every way. In France there are good cars and bad cars, just as there are good cars and bad cars here. There is a difference between French and American car design. It is the custom in France, even in the big factories, to entrust the design of cars to special designers. There are three or four such designers in Paris. I have worked with one of them. They look through the old list which is published in every language, so they can collect all the necessary data; then they design the car. There are a few cars which give very good performance, because they receive the best of attention. Everything in that line which the automotive industry of France produces comes from the brains of three or four men. After the design is completed, it goes to the factories. We are more interested in good production. There are two or three cars in the United States that are really refined. Your conditions are quite different from European conditions; so you must not be worried about recent reports favoring French cars as against the American car.

CHAIRMAN CRANE:—We have had experience in this country with economy tests. They were dropped a number of years ago, largely because they did not mean anything. I happen to know the condition of a certain car in one of the last of those tests. The rear-axle gear-ratio was 1½ to 1. The tires were special cord racing tires. The car was lubricated throughout with machine oil; not even heavy oil, far less grease. The engine had a specially high compression. There was a specially small carbureter. The car would start to roll at a touch. My only ride in this car consisted of leaving the factory one day and going ½ mile. The car stopped. We investigated and found that the gasoline was shut off. A few drops of gasoline had been left in the float-chamber and this was sufficient to propel the car for that distance. The actual contest was on a circular course and this car ran out of its scheduled supply of gasoline a little more than one-half way around. It had 1 gal. to operate on during the race, and was provided with 2 gal. to get home on. It did not get home but ran out of gasoline and had to be towed in.

H. L. HORNING:—It appears that Americans are just beginning to realize the importance of the friction losses in an engine. These losses establish the mechanical efficiency of the engine. Roughly speaking, it requires as much power to run some engines using heavy oils as it does to run the car along the highway. Thus, 50 per cent of all the power developed is lost. This is a very bad showing. A case which I have in mind is that of a

4½ x 6¼-in. engine having a 398-cu. in. displacement. Considering this engine at 1000 r.p.m., the following facts are important.

Grade of Oil	Pull, lb.	Friction Pull, lb.	Brake Mean Effective Pressure, lb. per sq. in.	Brake-Horse-power	Mechanical Efficiency, per cent
Vacuum Arctic	184	16	92	46	92
Vacuum A	180	20	90	45	90
Vacuum BB	170	30	85	42	85
Vacuum B	160	40	80	40	80

The most effective study can be put on piston design, to reduce the mechanical losses in the engine. The losses due to shearing the oil-film can be considered as about 50 per cent of the total losses, at 1000 r.p.m. An hydraulic pressure of 10,000 lb. per sq. in. is developed in an oil-film which cannot escape the rolling-up action such as occurs between the piston and cylinder wall at high speed. Grooves on or holes in the piston relieve the pressure. Recently I tested an efficient automobile engine which had the following satisfactory characteristics.

Engine Speed, r.p.m.	Mechanical Efficiency, per cent	Fuel Consumption, lb. per hp-hr.	Brake Mean Effective Pressure, lb. per sq. in.
600	92.5	58	72
800	91.0	54	75
1,000	90.5	55	78
1,200	90.0	55	78

With an engine of this type in a car weighing 3000 lb. empty, it is not impossible to make 24 miles per gal., or something over 38 ton-miles per gal. I feel that this is a very creditable performance when compared with the ton-miles per gallon and even miles per gallon of some of the smaller European cars referred to.

O. C. BERRY:—To add to Mr. Horning's remarks about the amount of power required to propel a car on the road as compared to the power used up in engine friction, I would say that I have recently tested a car weighing 3100 lb. including the driver and observer, and having a maximum of 3.1 ft. per sec. per sec. acceleration. It required 3.51 hp. to turn the engine over at a speed of 1000 r.p.m., with the throttle set as it would be set in driving at that speed, while only 2.85 hp. was required to propel the car at the corresponding 20 m.p.h. on a hard level road. These figures are characteristic of our "active" American cars, and help to show why so much better mileage can be obtained when the speed of the engine is reduced at the expense of accelerating power. The results of the recent economy tests in France were an eye-opener to me. A Voisin limousine weighing 5300 lb. made 28.3 miles per American gal. This looks high when compared with the customary performance of our American cars, and goes to show what the possibilities are in the way of improving our fuel economy.

I do not agree that an economy test is of no value. I grant that when some particular carbureter is used and adjusted for a certain car at a given speed to obtain the maximum possible mileage, regardless of performance, the results have little or no value. Before the economy test is started it should be required that the car meet very carefully specified performance tests. Under these conditions the results take on a real value. I would like to see the Society of Automotive Engineers, or some similar organization in this country, back up a series of economy tests occurring once a year. I feel convinced that they would result in a real benefit to the industry.

It appears to me that the matter of fuel economy has received less study than any other one feature of the American car. This is a mistake. We are in danger of a fuel shortage, a time when not all of us can ride for want of a sufficient amount of fuel, and those of us who do ride will pay well for our pleasure. The price of our fuel will tend to follow one of two standards. When the raw material is plentiful and can be had by anybody, the price of the finished product will be the cost of production plus a reasonable profit. As soon as the demand exceeds anything that can be produced from the raw material, the price tends to rise until it represents all that we are willing to pay. The French are paying about $1.90 per American gal. for their fuel. If such prices were demanded in this country it would have a serious effect on the whole automotive industry, and such prices are inevitable in the not distant future unless vigorous steps are taken. Hence the great value of any effort that will result in better economy on the part of our American cars.

The foreign engines do not have incorporated in their design any features resulting in high economy that we do not understand, nor do I feel that the American engineer is one whit less resourceful or well informed than the best in the world. I want to see us make a careful and exhaustive study of all the factors influencing fuel economy and set ourselves the task of exceeding the best results ever obtained by the English, French, German or Italian engineers. We ought also to go one step farther and design our cars so that the average driver can approach ideal results more closely than he can at present.

CHAIRMAN CRANE:—I think that Mr. Berry is right regarding the educational value of economy tests at this time, provided a scientific basis could be arranged for them. There is nothing like trying to get the maximum mileage per gallon of fuel out of a car. I hope the matter will be taken up and an attempt made by the proper authorities to formulate a set of rules for an economy test that will really cover stock cars and also what we might call stock driving. In the old economy test the driver was allowed to do anything he chose, and that resulted in a method of driving which is never used by the public. The cars, equipped as I have described them, will coast readily on a grade of about 2 per cent and keep it up indefinitely. They do this very slowly it is true, at 10 to 12 m.p.h., but with the engine shut off, that gains mileage at a great rate.

Our company started some years ago to put speedometers just back of the transmission. After watching this practice very closely for a long time, I do not agree that there is any serious discrepancy between the mileage run by the rear wheels and the front wheels, in ordinary service. That was indicated by tests made at the Brooklands race track in England; the difference was remarkably slight, and I imagine that this track was not particularly smooth in those days. The relatively short intervals of time between bumps on the road are not sufficient to make any noticeable change in the angular velocity of the driving-wheels.

E. W. WEAVER:—If the engine is kept running wide-open at a speed to develop the power that is actually required, we will get the greatest economy that it is possible to get. For instance, if it requires 2½ hp. to run the engine, if we could run it slowly enough so that

2½ hp. is all the power it actually develops, we would get a much greater economy. A series of tests shows that very plainly. That would be equivalent also to having gear-ratios that will allow this in the end.

CHAIRMAN CRANE:—There is no question that this is an absolute fact with the Otto-cycle engine. The more slowly it runs, the less the mechanical loss is; the higher we keep the compression, the better the thermal efficiency is. So, there is every reason to run the engine as slowly as is possible to develop a certain power. The only limitation to this is based on the ordinary design of engine that will not run below 100 r.p.m. and give any satisfaction at full load.

W. C. DAVIDS:—In regard to the transmission and the shifting of the gears, that requires so much strength and acrobatic action, would not the hydraulic transmission eliminate this?

MR. WILLIAMS:—The hydraulic transmission was made successfully over 20 years ago, originating in Minneapolis. It was tested in New York City and showed a power loss of only 15 per cent. They undertook to use it commercially in automotive vehicles, but it would heat up. Not only that, but any bit of sand or grit in the oil would be forced around with the oil through the passage-ways and cut them out. They did use that transmission to get any variation of speed and adjustment in lining up the guns on the United States battleships. There is one vital failure attendant upon the hydraulic transmission. You must still shift something for speed changes and must still control the engine. It is simply a change in gearbox arrangement.

MR. MANLY:—I have spent about 20 years and much money on hydraulic transmissions. They are being used today in turning the guns on American battleships and are very useful and effective. I have also built some for use on large motor trucks, for moving draw-bridges and other work of that kind. In regard to the heating effects, that is a difficulty which must be taken care of, but it can be overcome. As the temperature rises, the viscosity of the fluid must decrease. We have not found any fluid that does not have that characteristic but, on the other hand, the hydraulic transmission is not in the same category as the friction transmission. In connection with the matter of increasing the torque as the speed decreases, we can give an exact increase of torque, with a decrease in the speed, up to any predetermined point. It is merely a matter of design. Something will be accomplished in connection with hydraulic transmission, especially for heavy work.

In regard to the light passenger-car, during the past 20 years I have been attempting to apply the hydraulic transmission but have found that it is not necessary with it. However, in regard to heavy work such as is required of trucks, tractors, road rollers and the like, I think the hydraulic transmission has a very large field. I presented a paper[5] before the American Society of Mechanical Engineers, in 1911, and one before the Automobile Club of America in 1912, which give rather interesting data in connection with this subject. The fault that Mr. Williams criticized in connection with the design he looked at can be overcome.

MR. WOLF:—Referring to Mr. Williams' question about the pump wearing out, I would say that in the particular system mentioned the pistons force the oil out as they come toward the center. Each piston-head was cupped and all foreign matter and sediment would collect in the cup, due to centrifugal force. It was found that this in

[5]See Transactions of the American Society of Mechanical Engineers, vol. 33, p. 851.

no way impaired the working of the system. In fact, when dismantled after two or three years of service, all parts were found in good order. The cylinders and pistons were free from scoring. The piston-heads held considerable grit.

It is probable that chassis weight can be reduced still further by more extensive use of alloy steels. Due to its superior characteristics under proper heat-treatment, molybdenum steel is likely to receive the attention of those who are anxious to eliminate excess weight. It seems to me that in frame construction, for instance, effort in this direction will equal or surpass any result that might be obtained by the use of plywood, and at the same time make a far better manufacturing proposition. Rather than resort to extreme means, of which I consider plywood one, I think it would be better to expend the same energy in refining what we already possess.

With reference to the churning of the grease in the transmission, I believe that we should design the transmissions with a small circulating pump so that it can handle light oil and deliver it to the face of the gears. Many years ago the De Dion car introduced such an arrangement and it is now used in a number of tractors. The same recommendation applies to the rear axle, where an oil-pump can be added, or the two applications can be worked together. The pumping loss will be far less than the drag of the grease, especially when the grease is cold.

It was stated that when a wheel goes over a rough road, the wheel would not accelerate due to its inertia. This flywheel effect undoubtedly is considerable, but another thing to be considered is the action of the differential. The conventional differential is too efficient, although it sounds paradoxical to condemn efficiency. When one wheel leaves the ground, the engine tends to speed it up through the differential; this has been observed in high-speed motion pictures that have been slowed down. In one particular case a truck rode over an obstacle probably 5 in. high and, when the one wheel left the ground,

one could easily see it accelerate. If this happens with the truck wheel having so much greater mass, it must occur in the case of the lighter passenger-car wheel, and I believe that energy is wasted and tire wear increased by this action. It would be better if differentials did not function when the vehicle is traveling straight ahead, but only when making turns.

I believe that a constant-speed engine with a widely variable transmission system would not result in the engine being used continually at a constant speed. Other systems have indicated this. What we desire most in this combination is the variable transmission ratio, rather than the strictly constant engine speed. In this way we could approximate more closely the desirable results stated by Mr. Nelson in his paper on the Fuel Problem in Relation to Engineering Viewpoint.[*] A great portion of the time that a car is on the road, the engine can easily handle the load on a higher gear-ratio; and, if a practical widely variable transmission were available, it would go far toward solving the fuel problem by working the engine nearer its point of maximum efficiency. For the variable conditions encountered on the road, the present limited gear-ratios are not variable enough to obtain the best efficiency of the engines.

In regard to changing gears, which is a thing that the American driver does not like to do, I believe that if we could have silent operation this would help toward making the public willing to do more gearshifting. There is undoubtedly considerable embarrassment to the ordinary driver who does not wish his friends to know that he must negotiate a grade in one of the lower gears. The noise also produces a mental strain on the driver. Both these conditions could be largely overcome if the gearshifting action were quiet a considerably larger portion of the time. I believe that steps other than those that already have been attempted along this line could be taken to decrease the noise considerably, although it could not be overcome entirely.

FUEL RESEARCH DEVELOPMENTS

BY C. F. KETTERING

THE author first refers to the remarkable progress in fuel research work during the past year and then states that there is a "dead-line" in the utilization of fuel in internal-combustion engines beyond which progress cannot be made. The automotive industry must cooperate with the oil industry and find out what and where this dead-line is; it must know the end-point of fuels obtainable five years hence.

The two distinct divisions of the fuel problem are the fuel distribution in multi-cylinder engines and the chemical changes that occur inside an engine cylinder during combustion. Considering and explaining an elementary case, that of the combustion of hydrogen and oxygen, the components of combustion energy are stated to be gravitational, kinetic and barometric, and these, in turn, are considered and analyzed in considerable detail, with the aid of charts, formulas and diagrams illustrative of molecular structure. Other charts show the normal combustion of propane, its abnormal combustion such as occurs during knocking and the method of calculating

the knocking value of an internal-combustion engine fuel.

In Mr. Kettering's opinion, regarding any theory, the greatest difficulty is to obtain a proper conception of the terms employed in its development and to apply this knowledge correctly. This idea is amplified and the strange fact that substances of apparently diverse composition are in reality made up of the same chemical constituents is illustrated by statements regarding several such substances that have been chemically analyzed. That engineers must think of heat in terms of molecular velocity is emphasized and it is stated that the proper fuel mixture for an internal-combustion engine is not dependent upon the molecular construction of the fuel.

Engine friction is one of the most difficult problems with which an engineer must deal and it must be reduced in some manner. The present need is to burn less fuel per car-mile. Numerous charts of indicator cards obtained when using the different available fuels in an internal-combustion engine are exhibited and the different characteristics of the performance of each fuel explained. [To be printed in an early issue of THE JOURNAL]

[*]See THE JOURNAL, February, 1921, p. 101.

VOLATILITY OF INTERNAL-COMBUSTION ENGINE GASOLINE

BY FRANK A. HOWARD

AFTER stating that the meaning of the term "gasoline" seems to be generally misunderstood for the reason that it has been assumed that gasoline is, or ought to be, the name of a specific product, the author states that it is not and never has been a specific product and that although gasoline has a definite and generic meaning in the oil trade it has no specific meaning whatever. It means merely a light distillate from crude petroleum. Its degree of lightness, from what petroleum it is distilled and how it is distilled or refined are unspecified.

Specifically, "gasoline" is the particular grade of gasoline which at a given moment is distributed in bulk at retail. It can be defined with reasonable precision as being the cheapest petroleum product acceptable for universal use as a fuel in the prevailing type of internal-combustion engine. The author places emphasis on the three factors of this definition: (a) the cheapest product, (b) its universal use and (c) the prevailing type of internal-combustion engine.

The author's purpose in this paper is to clear away some of the haze which surrounds the word "gasoline" and with regard to what volatility is with reference to engine gasoline to show how much of the difficulty is inherent in the fuel and how much of it arises from the failure of automotive engineers, collectively, to attain a high average of perfection in the handling of the fuel to develop power.

Ordinary engine gasoline of the grade now sold possesses sufficient inherent volatility to take and maintain the condition of a gas at a temperature at or below average intake-manifold temperatures. Manifold condensation seldom, if ever, occurs and cylinder condensation is even less probable. The phenomena answering to these names are in fact mainly the visual evidences of the failure of the vaporizing device to function. Fuel once vaporized must stay in that condition; hence, if liquid is found beyond the vaporizer, it reached there as a liquid.

These conclusions are based on an examination of the fuel itself. The volumetric proportions of a combustible mixture are considered in detail in the paper and the physical meaning and measurement of volatility are fully discussed, tables of vapor tensions being given and the special apparatus developed to determine the vapor tension of gasoline being exhibited and described. Following this a full discussion of the requirements for full utilization of inherent volatility is presented, the conclusion reached being that the problem resolves itself into the further development, improvement and wider use of the hot-spot. [Printed in the February, 1921, issue of THE JOURNAL]

THE NATURE OF FLAME MOVEMENT IN A CLOSED CYLINDER

BY C. A. WOODBURY, H. A. LEWIS AND A. T. CANBY

THE nature of flame propagation in an automobile engine cylinder has, for some time, been the subject of much discussion and speculation. However, very little experimental work has been done on flame movement in closed cylinders with a view to applying the knowledge directly to the internal-combustion engine.

It has become recognized that knocking is one great difficulty which attends the use of the higher-boiling paraffin hydrocarbons, such as kerosene, and that knocking is one of the major difficulties to be overcome in designing higher compression and hence more efficient engines. It was desirable, therefore, to determine, if possible, the nature and cause of the so-called fuel knock in an internal-combustion engine.

The work described in this paper was undertaken to determine the characteristic flame movement of these various fuels and the physical and chemical properties which influence this flame propagation. The scope of the work is specified and the arrangement of the apparatus for measuring flame propagation is illustrated and described. Flame movement at normal temperature and pressure was then investigated, the results obtained are shown in charts and a table and these are commented upon in detail. The influences of turbulence and of temperature and pressure on flame propagation are treated in like manner, followed by a lengthy discussion of autoignition and the nature of fuel knock, which also is illustrated. [Printed in the March, 1921, issue of THE JOURNAL]

AIR-TEMPERATURE REGULATION EFFECTS ON FUEL ECONOMY

BY REUBEN E. FIELDER

TWO serious problems confront the automotive industry in connection with the present fuel shortage, the securing of a much higher degree of fuel economy with existing equipment and the matter of future designs. These problems are of nearly equal importance.

Because its fuel bill constitutes the second greatest item of expense for the Fifth Avenue Coach Co., operating in New York City, it is constantly experimenting with devices of various kinds to improve fuel economy. Of the different devices that it has tested, the thermo-static temperature-control for the carbureter appears to afford greatest possibilities of saving, and the author presents the results of tests of this device in actual service on motor vehicles.

The thermostat is shown and described and comparative tests made with and without this thermostatic-control device, using the same engine, carbureter and similar equipment, under the same atmospheric conditions, are discussed and analyzed with the aid of tabulated data and charts. The matters of temperature

variation and the volatility of fuel are treated in a similar manner, consideration then being given to what the desired manifold temperature is. Volumetric efficiency is discussed in some detail.

The paper was presented with the primary idea of bringing out constructive criticism. The company believes that the principle of thermostatic control is correct, but that its detailed application is still a matter for further experiment. That there are certain periods during the year when the average internal-combustion engine functions with the minimum amount of trouble is scarcely open to argument. This is because at that time the atmospheric temperature is right. The company's idea is to select this period and standardize it for use throughout the remainder of the year. [Printed in the February, 1921, issue of THE JOURNAL]

FUEL PROBLEM IN RELATION TO ENGINEERING VIEWPOINT

BY A. L. NELSON

THE author states preliminarily that it is believed that never before in the history of the Society of Automotive Engineers has a single problem been so universally studied as the fuel problem that is confronting the industry today. It is also believed that never before has the industry had a problem which includes such a wide scope of work. The solution calls for the service of every class of engineer, inventor and scientist.

The paper does not attempt to give highly scientific information; its real purpose is to appeal for a broader viewpoint and give illustrations and tests which show that the solution of a problem may lie in an entirely different method than that which often becomes stereotyped by sheer usage, rather than by its specific merit. In the solution of the fuel problem we undoubtedly will have to change some of our old habits, replacing them by studiously worked out viewpoints. The further object of the paper is to seek the correlation of the experience of the entire engineering fraternity, to obtain the comments of its members and receive any suggestions they may offer.

After giving recognition to the cooperation and assistance already received and making general comments upon the desirability of radical changes in viewpoint, the author enters upon a discussion of the engine power required to drive a car at constant speed and the effect of using higher piston compression ratios, illustrated by a table and chart, with a view to demonstrating the value of modified viewpoint. In like manner he discusses the constant-clearance aluminum piston and the fuel vaporizer. The basic principles of the engine used in testing are next considered and copiously illustrated, together with the apparatus used in the dynamometer and practical driving tests that were made. Charts show the percentage comparison of results and these are explained.

After a discussion of ideal economy, it is stated that the tests show that an absurd waste is rampant in the present method of applying the indicated engine power and that this subject should be studied from every angle. A close study from the brake-horsepower standpoint may justify changing both transmission and rear-axle drive ratios. The latter combinations, together with engine developments, look the most promising at present. The progress we make will be measured by the extent to which we expand our engineering viewpoint. [Printed in the February, 1921, issue of THE JOURNAL]

RESUME OF BUREAU OF STANDARDS FUEL STUDY

BY H. C. DICKINSON

THE author states that considerable thought has been devoted recently to the relation of fuel end-point to fuel economy. It has been shown that, provided an intimate mixture of fuel-vapor and air is secured, such a mixture will not condense at the ordinary temperatures of the intake. However, on the contrary, crankcase dilution, an excess of deposited carbon, low mileage per gallon of fuel and ignition trouble are being experienced. There appears to be a discrepancy between the efficiency that should be attained and what is actually attained. To investigate this the Bureau of Standards undertook a brief series of experiments to rough out a line of procedure.

Regarding compression of a dry mixture, curves are shown to illustrate that gasoline vapor compresses when "dry." Detonation was evident when using one spark-plug and there was no detonation when using two spark-plugs. After preliminary experiments of the nature already indicated, a pressure indicator was used, at pressures just on the verge of detonation, to find the exact point where detonation occurs. Charts are exhibited to show the location of the piston with reference to its center position, with one spark-plug and with two spark-plugs; and the effect of spark advance on the maximum explosion pressure and brake-horsepower, using one spark-plug. An explanation which goes into considerable detail supplements the charts. [Printed in this issue of THE JOURNAL]

AUTOMOBILE EXHAUST GASES AND VEHICULAR-TUNNEL VENTILATION

BY A. C. FIELDNER, A. A. STRAUB AND G. W. JONES

THE data given in this paper were obtained from an investigation by the Bureau of Mines in cooperation with the New York and New Jersey State Bridge and Tunnel Commissioners to determine the average amount and composition of the exhaust gases from motor vehicles under operating conditions similar to those that will prevail in the Hudson River Vehicular Tunnel. A comprehensive set of road tests upon 101 motor vehicles including representative types of passenger cars and trucks was conducted, covering both winter and summer operating conditions.

The cars tested were taken at random from those

offered by private individuals, corporations and automobile dealers, and the tests were made without any change in carbureter or other adjustments. The results can therefore be taken as representative of motor vehicles as they are actually being operated on the streets at the various speeds and on grades that will prevail in the tunnel. The information obtained can be applied also to ventilation problems of other vehicular tunnels and subways.

The vehicles comprised six representative classes, which are stated, and the test conditions and methods are described in detail. The method of computing the results is outlined and the results are stated and analyzed in the text and in tabular form; a photograph and charts are presented.

The average composition of the exhaust gas, the completeness of combustion and the percentage of carbon dioxide are discussed in detail. A concise summary, in nine specific sections, concludes the paper. [Printed in the April, 1921, issue of THE JOURNAL]

THE DISCUSSION

E. A. SPERRY:—There is a possible explanation of the extra heat loss to the jacket at the moment of detonation. Mr. Midgley and Mr. Kettering have always found a deposit of carbon in the cylinder or exhaust caused by detonation. Also, there is seen through the window a brilliant light at the time of detonation. Inasmuch as radiation is as the fourth power of the temperature, it occurred to me that the black-body radiation of the carbon particles present might help to explain the extra loss of heat to the jacket.

THOMAS MIDGLEY, JR.:—That is a reasonable explanation but we have one or two other points to consider. We have studied the spectrum of the light through a window in a cylinder-head and watched the light of combustion from many different fuels. It is true that with kerosene or gasoline the light is very intense during detonation, as compared with a comparatively weak light when there is no detonation; but with benzol as a fuel, it being rich in carbon, the light is just as bright as during detonation, although there is not the heat or pressure that there is during detonation. I suggest as a possible explanation that in knocking, which is a differential burn of the hydrogen that leaves the carbon behind, the carbon is actually in a gaseous condition following this rather active period. If a piece of steel is put into a steam bath of 212 deg. fahr. and another piece is put into hot air at 212 deg. fahr., the piece that is in the steam bath will heat up more quickly than the one that is in the hot air. If we have gaseous carbon in a detonating explosion, it is certain to produce heat more quickly than simply some hot solid particles.

We encountered a condition in which we had a definite green-band spectrum with the spectroscope during knocking. My colleague said that this showed carbon. We hope to have some definite information about this spectrum ready for the Summer Meeting.

FRED WEINBERG:—I do not believe in Mr. Midgley's theory. We have been unable to gasify carbon; it has never been done. We were, however, able to melt carbon, two years ago. The condition under which carbon melted was the extreme high temperature of the electric arc, in a vacuum. Under ordinary atmospheric conditions carbon will not melt.

L. M. WOOLSON:—I think we must acknowledge that Mr. Nelson's paper is one of the most complete ever read on the subject and that he should be complimented for the very full presentation of data which less broad-minded members might consider confidential and in the nature of trade secrets. I am inclined to take issue with Mr. Nelson with regard to his theory that we need a change of viewpoint. What we actually need is closer concentration on our detail problems. We have been spending most of our time in developing engines for next year's market, adding accessories from time to time. These have included electric starting and lighting, or even electric gearshifts. We have tried all kinds of valve arrangement and drive, starting out perhaps with an L-head engine, testing every other conceivable arrangement and then probably finishing up with an L-head design. Now that these matters are all settled, we have some time available for meeting the problems presented by the cars that are now in service. Most of us are trying to increase the gasoline mileage of our cars; there is, of course, the bogey of gasoline shortage to urge us on in our work of conserving fuel. The advertising departments of various motor-car builders have done some splendid work in securing high gasoline-mileage, on paper. Mr. Nelson has done better, showing that we can secure nearly 50 miles per gal., if we use rear-axle ratios that will rob the car of most of its performance on high-gear, and high-compression engines which will knock badly with ordinary fuel. Nevertheless, I would not accuse Mr. Nelson of being visionary; he ought to be congratulated on setting up a target for us to shoot at, even though we need long-range guns to hit it.

There is one rather important point in the matter of fuel saving that Mr. Nelson has not touched upon and warrants most thorough investigation. In the test shown in Fig. 23 of his paper he gives a fuel consumption of 1.125 lb. per b.hp-hr. at 1000 r.p.m. of the engine, which represents average driving conditions. It is perfectly possible to reduce this consumption to about 0.93 lb. per b.hp-hr., representing a gain of something like 20 per cent in gasoline mileage. All we have to do to obtain this additional mileage is to construct carbureters that will give a lean mixture under average driving conditions, and this can be done without hurting the acceleration or wide-open pulling. Most carbureters are designed to give practically a constant air-gas ratio throughout the range, although experience has shown that this is not required in actual operation. While this possible 20-per cent saving is small in comparison with some of the savings pointed out by Mr. Nelson, it is within our reach without any accompanying disadvantages.

Mr. Nelson does not offer any conclusive evidence that sufficient heat is furnished to the mixture under average driving conditions. The ability to accelerate well in cold weather without pulling the choker soon after staring certainly does not prove the point. That depends on how rich a mixture the carbureter was set to furnish at the time. Although I have been for some time in favor of rather higher intake-mixture temperatures than are usual, it is only recently that I have found that still higher temperatures are desirable from the standpoint of maximum economy and maximum performance in acceleration. I believe that we should refer to actual intake-mixture temperatures when we discuss methods of fuel vaporization, instead of to car performance in a general way or to other less specific data. There is no question that there is a certain desirable range of mixture temperatures that will probably apply to all engines under the same conditions, and I believe we ought to know what that range is. The Bureau of Standards has shown that greatly improved acceleration can be obtained by raising the mixture temperature, but I believe it has not inves-

tigated or at least reported the great gains in economy possible under ordinary driving conditions with mixtures at rather high temperature, given, of course, suitable carbureter adjustment. I venture to say that the desirable temperatures will be found to be about 100 deg. fahr. above those obtaining in the average intake-manifold.

It appears that there will be considerable variation in opinion as to the significance of actual manifold-temperature measurements. As pointed out by Mr. Howard, it is not desirable to heat the air unduly, but it is necessary to apply fairly high temperatures to the fuel. In one case we may have an average mixture-temperature of 120 deg. fahr. and a relatively poor degree of vaporization, and in another case with the same average temperature almost complete vaporization. Nevertheless, we must determine the best average mixture-temperatures under different conditions, and Mr. Horning's suggestion that these be determined in terms of carbureter efficiency is a real constructive step. This work is to be undertaken by the Bureau of Standards and the Bureau of Mines in the immediate future, if the necessary funds can be secured.

Mr. Nelson made some rather positive statements regarding the value of certain types of aluminum piston, which I believe should be accepted with reservations. It is only after we have had a great amount of operating experience under average driving conditions that we can be sure of our ground in a case such as this.

A. L. NELSON:—I am glad that Mr. Woolson is inclined to take issue with me relative to a change in engineering viewpoint. I believe we have been doing for years what Mr. Woolson suggests; nevertheless, we have perhaps paid too close attention to mere details and our feet are not yet touching the ground when it comes to the fundamentals underlying our problems. Mr. Woolson gives a rather unique picture of the development of a certain new engine which started out with an airplane birth, so to speak, and wound up in a rather conventional L-head type, the type that has been in use for years, particularly in low and medium-priced cars. It is hard to understand why the engine referred to has any bearing on the matter of valve arrangement, as Mr. Woolson infers.

Mr. Woolson apparently believes that almost all advertising departments are proverbial liars on gasoline mileage. He says that I show still better results, namely 50 miles per gal., but at a sacrifice of good performance. There is not one fair-minded capable engineer who will not agree with me relative to the ideal mileage possible as shown in Fig. 33 of my paper, under the conditions set forth. Furthermore, we do not have to use engines that knock badly. If Mr. Woolson had looked more carefully into my paper, he would have found increases in economies over twice as great as what he cites as possible at ordinary driving speed. In the test shown in Fig. 23 of my paper, we get 1.125 lb. of gasoline per b.hp.-hr. at 28.6 m.p.h. Mr. Woolson places stress on this figure and contends that by proper carburetion it is possible to make this 0.93 lb. per b.-hp.-hr., representing a gain of 20 per cent. However, I also show, in Fig. 27, results slightly better than 0.93 lb. per b.hp.-hr., and in Fig. 26 at this same car speed we get 0.75 lb. per b.hp.-hr. This is a 24-per cent increase in gasoline mileage over what Mr. Woolson claims proper carburetion will give. For the cases cited above, the carbureter had relatively very little to do with the results obtained. I will mention a little later the results obtained so far as the carbureter is concerned.

I am sorry that Mr. Woolson looked for conclusive evidence in my paper with regard to whether the proper amount of heat was furnished under average driving conditions. He should read the second paragraph of my paper more carefully. The result of the tests shown in Fig. 28 indicate that the vaporization at partial loads was not really bad at least; also, the indicated thermal efficiencies of the tests in Figs. 26 and 27 are not bad. Mr. Horning points out that the results come within his expectations, after a study covering fundamentals which were not treated in my paper. The results, although not perfect, are found to be fairly good. To go into the details of making the results possible is beyond the scope of my paper. As to whether the mixture was over-rich when accelerating with the engine cold, the mixture used for this open-throttle condition was one which gave a gasoline consumption of less than 0.52 lb. per b.hp.-hr. Comparing this with the results of our best aviation engines, which do not carry fan and battery-charging loads, it appears that an over-rich mixture was not used in tests without an accelerating pump. Mr. Woolson admits that he found recently that higher temperatures give better results. He will find that there is still further room for improvement, and also that there are new devices which have considerable merit.

Mr. Woolson pleads for the acceptance of my statements regarding the aluminum piston, with reservations. During the war I was in the gun business for the Government. We learned that we could accomplish what we went after. It required hard work, but I think we demonstrated to all our Allies that we could shoot more accurately than they could when it came to mixing bullets and propeller blades. In view of those records, I will trust to having the statements I made relative to the aluminum piston accepted without any reservations whatsoever until the results claimed can be verified by personal observation.

There is one matter in connection with these tests in regard to which I do not wish to be misunderstood. A case in point is Mr. Woolson's remarks relative to the improvements that can be made in performance at a few fixed car speeds and concerning additional tests that are desirable to make the investigation more complete. The latter had to be omitted from the paper for brevity's sake; also, the time for conducting the tests was very limited. The first test was run on Dec. 18, 1920, and the last one on Dec. 28. The results show clearly what can be done with one carbureter setting over a range of speeds from 10 to 60 m.p.h. and at wide-open throttle for speeds from 400 to 3200 r.p.m. The results that it is possible to attain under ordinary limits and with diligent care are far in advance of those given in the paper. The thing to remember is the wide range of conditions that were met with one carbureter setting. The ultra results at a few speeds are comparatively easy to obtain.

C. P. GRIMES:—I think that Mr. Nelson should be complimented upon the way he has presented his paper, inasmuch as he has approached the subject from a definite viewpoint. About the time the war started, Mr. Nelson investigated guns and was able to develop a cam, used in the Nelson gun control, which excelled any developed by those who had spent years in the gun business. Sometimes we work in one line and do not go far enough afield to get a real perspective of what we are trying to do.

I am most interested in the general car performance. Mr. Nelson has shown in his paper that we are using a power factor of 15 per cent; I mean that the power used is only about 15 per cent of the available power. Under

ordinary conditions of 20 to 30 m.p.h., car owners would soon go broke. We have all been using gasoline with the power factor not to exceed that. I made some tests on the road in which I obtained some rather interesting data. We ran at 20 m.p.h. over a level road at 10, 20, 30 and 40-deg. spark-advance. I found that every time I advanced the spark I obtained a few more miles per gallon. In general, the automatic spark-advance is fairly common. We can set that at the full-power condition. I think that shortly someone will arrange to have the spark at partial-throttle conditions advanced to that point which gives the best result in miles per gallon of fuel.

There is another method of obtaining the horsepower which really is required to drive an automobile on the road and which is available to that automobile. The system of adjusting the throttle-valve that Mr. Nelson used on the race-track at Indianapolis is very good. However, he said nothing about where he carried the spark. It is to be presumed that he exercised the same care in the location of the spark as in the location of the throttle. That would require, of course, a spark protractor on the automobile. This is simple to apply. Take the starting-crank off and replace it with a disc of tin; then turn a wooden plug to fit the inside of the starting-crank hole, so that it projects somewhat, and put a steel pointer on it. Set cylinder No. 1 on a dead-center position. After marking off a few degrees on each side, take a file-handle and a piece of flexible cable and run the wire from the cylinder around this round handle and touch the center with the pointer. The man who drives the car can set the speedometer and watch that little spark jump, wherever it is. If anyone had tried to tell me a short time ago that a 5-deg. difference in the spark-advance makes a difference in the ability of the automobile, in regard to the acceleration, economy or hill-climbing, I would have thought him wrong. Long ago I made tests with spark protractors in which it seemed that there was plus or minus 6 to 8 deg. of spark-advance. I have changed my mind because about 50 tests which I made all seemed to check.

The subject of acceleration was discussed before the Indiana Section of the Society in February, 1916. The method of using a stop-watch and an ordinary speedometer was set forth. The mass of an automobile traveling along a level road has a certain amount of energy; one-half the mass times the square of the speed. If we decrease the speed the car has not so much energy but a certain number of seconds is required to dissipate it. Ordinarily, when we run a car at 3 m.p.h. and the driver accelerates it, we find the best spark for acceleration and snap the stop-watch at 5, 15, 25, 35, 45 and 55 m.p.h. Then we figure out the number of seconds, weigh the car on ordinary scales and get the number of accelerations. I am speaking of these things because I hope to encourage more engineers to find out the exact resistance of the car and its weight, and put it on the dynamometer and continue the research which Mr. Nelson has started. I have made tests for acceleration on a number of different cars. I have been rather surprised to find that weight does not seem to be the main factor at all. We know that 60 per cent of the resistance, at a speed of about 20 m.p.h., is wind resistance; the remainder is bearing friction and top resistance.

In regard to the heat in manifold conditions, I have observed that as long as the air is kept at ordinary temperature, the hotter the hot-spot, the better are the economy and the acceleration.

MR. NELSON:—Mr. Grimes' method of studying car performance is indeed interesting, particularly the method of determining the load factor. This is a quick and ready means of getting approximate results. My experience with speedometers has, however, been very unsatisfactory. The inertia effects of certain parts are so marked in some types of instrument that I would never think of using them to determine car acceleration. When the car acceleration is increasing, the speedometer lags; and when the acceleration is decreasing, the speedometer runs ahead of the true reading. Driving a high-grade car I pulled out the reset while the car was standing. After doing this, the speedometer quickly showed 20 m.p.h. and, of course, soon showed zero again. An instrument which is so sensitive to shock certainly cannot be used in laboratory work. These remarks necessarily do not apply to all types of speedometer, but if care is not used to select the type of instrument most suitable for testing purposes, the results will be very questionable.

In reference to the spark location used in the tests, only one setting was used. The automatic advance took care of the spark location. Our experience has been that, with a proper quality of mixture, the spark-advance is not nearly so important as when the mixture is slightly wrong. In checking the results as mentioned by Mr. Grimes, we have found almost invariably that the quality of the mixture was wrong. This may vary with different engines and Mr. Grimes' suggestion is worthy of careful attention.

HERBERT CHASE:—Mr. Nelson has hit upon a point which few others have emphasized, namely, the necessity of getting better economy under the part-load conditions that obtain in the average passenger-car, particularly, during a very large percentage of the time of operation. Testing is done at full load almost entirely and few engineers give the consideration that they should give to the matter of load factor mentioned by Mr. Grimes.

Mr. Nelson has shown one way in which it is possible to increase the fuel economy at part load, and it is a subject deserving of further consideration. There are other methods of accomplishing the same thing. One is to build a constant-compression engine. I mean an engine of conventional type that is a constant-volume engine, but which has constant compression at all loads. This has been done in England by Mr. Ricardo. Others in this country have experimented with the same thing. I know one engineer who has a six-cylinder car of about average size on the road today, with which he claims to be getting close to 60 miles per gal. Such a performance, if it can be realized commercially, would constitute a long step in advance. The method in this particular case is always to take into the cylinder practically the same amount of air controlling the amount of fuel in proportion to the load demand. The rich mixture that is taken in through one additional valve is, to a certain extent, localized in a portion of the combustion-chamber adjacent to the spark-plug. Then there is always an excess of air under part-load conditions. At wide-open throttle, there is simply enough air to burn the entire charge. That is one way of getting this desirable economy at part load. There are other methods. Variable valve-timing will help. Mr. Sargent has presented papers before the Society in which that has been the theme, but it is a matter that should be given further and more thorough study than it has received to date. We have done much in the way of adding accessories, hot-spots and what not, all of which are commendable and have produced some increase in economy, but we must, if we can, get rid of the basic thing which causes lack of economy, namely, the throttle, which

can never be efficient as long as it continues as a throttling engine.

EDWARD D. THURSTON, JR.:—In connection with Mr. Fielder's work, Fig. 2 of his paper shows the results of a test as to the saving in fuel consumption and increase in horsepower obtained as a result of using the thermostatic control. Also, in Table 1, he presents an economy test which gives the power developed, the fuel consumed and the manifold temperature. The changes are rather small and I ask Mr. Fielder if the ratio of fuel was precisely the same under the two conditions; that is, whether the carbureter was readjusted to have the same ratio of fuel. Very little variation in the carbureter setting or very little change in the mixture would account for a difference of only 0.04 lb. per hp.

In connection with Mr. Howard's paper, he speaks of determining the vapor pressure of gasoline by introducing a certain amount of it into a barometer tube, the increase in pressure being the partial pressure of the gasoline. That seems to me to be perfectly practicable in the case of a simple liquid, or, if a small amount of gasoline is placed in a tube, the pressure will surely rise a certain amount; but I have found by experience that it makes a great difference how much gasoline is put in. If we introduce 2 or 3 cc. of gasoline, we may find a pressure-increase of 2 or 3 in. of mercury; if we put in 5 cc. of gasoline, there may be twice that amount of pressure increase. What is the vapor rating of a gasoline? Is it the first rating or the second? I do not understand yet how we are to get the vapor pressure of gasoline.

In connection with the cooling or the drop of temperature in the inlet manifold, that introduces an interesting point in regard to measuring the temperature in the manifold. This has been brought rather forcefully to my attention in the last few weeks because I have been doing some work along this same line. In some cases at least the apparent temperature drop through the carbureter is greater than could be accounted for by the evaporation of all of the fuel. In other words, if we evaporate the entire pound of fuel, we would have 130 heat units available. The fall in temperature of the air times the specific heat times its weight is greater than 130. Obviously, something is wrong. Mr. Howard's paper has given me a clue to the explanation. The mixture is probably still wet, some of the unvaporized fuel has become lodged upon the temperature-recording device and, by its evaporation, has given us a false reading of the mixture temperature. I cannot see that this will be very different with different types of measuring instrument. Whether we use the thermocouple or the thermometer, the result will be about the same and that rather leads us to suspect that some of the manifold temperatures we are recording are not the average or correct temperatures; that they are too low, on account of vaporizing some fuel on the temperature-recording element.

R. E. FIELDER:—No attempt was made to keep the ratio of fuel to air precisely the same. Conditions, physically, were kept the same as nearly as possible throughout all comparative tests; the magneto timing and the carbureter setting remained the same.

J. D. GILL:—For the past several years, as a refiner and marketer of gasoline, I have heard many complaints about commercial gasoline. For the past three years I have attended the Society meetings, particularly the fuel sessions, in the hope that I might find out just what the automotive engineering profession wants for engine fuel.

Perhaps the petroleum refiners could not provide just what is wanted, because immense quantities of engine fuel are being demanded, but the refiners do wish to know at least what is desired and having this information would try to live up to such broad specifications as might be determined.

I have not seen any direct comparisons of different kinds of engine fuel, with respect to either accelerating power or fuel economy. The conclusion I have reached after letting my mind run over the many accessories that have been added to the car to assist carburetion, vaporization and the like, and the many fuel experiments that have been performed, is that, if certain things are done, such as the installing of hot-spots, satisfactory results will be obtained with the present-day commercial grade of gasoline.

Two outstanding factors have been mentioned repeatedly in connection with the burning or utilization of engine fuel. One is that, under certain conditions, knocking ensues; the other is that an undesirable dilution of crankcase oil results from the use of present-day fuels. In Mr. Howard's paper it was shown that, under proper conditions, fuel taken into the system is perfectly volatilized and remains a dry gas. This is the condition that was sought to eliminate the dilution of crankcase oil. The statements made by Mr. Howard were confirmed by the experiments described by Dr. Dickinson, in which the vapor tension of practically all the components of gasoline which he examined was below the corresponding values on the adiabatic curves, showing that the material would remain dry at the ordinary compression pressures in the cylinder.

Keeping these things in mind, but passing to one of the other factors for a moment, we have seen also that knocking results with lean mixtures in the cylinders. In the present-day engine, having a long manifold system, there is no doubt that the distribution of the fuel is not uniform and that different cylinders receive different quantities of the power supply. May it not then be that some of this knocking which we have been talking about is not at all due to the character of the fuel itself, but to the lack of the fuel in proper quantity at some certain cylinder? I repeat that all that has been said indicates that if "certain things" are done, the gasoline that we are using today will give satisfactory results.

However, we can accomplish our purpose most readily by utilizing the physical characteristics of gasoline cited by Mr. Howard. If in a water system that has a reciprocating pumping unit we desire a continuous flow of water, we put into the system somewhere between the pumping cylinder and the delivery point a reservoir, so that the pulsations of the pump are lost in the large volume of the reservoir and the flow of liquid is continuous. That is about what we desire, it seems to me, in an internal-combustion engine. Reverting again to Mr. Howard's statements and their confirmation by Dr. Dickinson, we find that we can make a perfectly dry mixture and that it will stay dry without the application of heat; but time is required for this complete volatilization of the fuel.

Suppose we were to put into the system, somewhere between the carbureter and the place where the fuel mixture enters the cylinder, just such a reservoir in which the "pulsations" from the carbureter would be thoroughly mixed with the air and given time for vaporization. Suppose also that the mixture which finally passed out of this reservoir was in conformity with Mr. Howard's idea of a dry complete mixture of somewhat under 2 per

cent of fuel mixed with air. Would we then have the knocking which comes from poorly fed cylinders in the system, and would we have the excessive crankcase dilution which has been a source of very great annoyance within the last few years?

I feel that perhaps some of the criticism which arises from crankcase dilution may not be justified solely by any increase in dilution that we now experience; we are inquiring much more closely into performance today than we did years ago. Crankcase dilution, of course, always existed, but perhaps we can agree that it has been excessive. Can we not improve conditions by making the mixture complete and dry, not by using the hot-spot or other means which have been placed on the market, but simply by giving the fuel sufficient time in which to vaporize completely and mix with the air before it passes into the cylinders?

PRES. J. G. VINCENT:—We should not overlook the fact that the average car is working much of the time under conditions that are not ideal. The automobile is used to a great extent for business now, and many trips in cold weather are just to the house, the store or the office. In many cases such trips do not occupy more than 10 to 15 min. of time in very cold weather. We ought not to conclude that all these devices perform as well as they should under such circumstances.

F. C. MOCK:—In our organization we are not sure that the volatility of a mixture of a series of elements can be determined by separate measurements of the volatility of each element. Some years ago we seemed to find that when 56 to 58 deg. Baumé Mid-West gasoline was introduced into about 15 times its weight of air at atmospheric pressure, only about 30 per cent of the gasoline would evaporate in an indefinite length of time. A fan circulation was used to avoid local segregation of the vapor. We did not follow through the method described by Mr. Howard of determining by fractional divisions the amount that should evaporate, but I am sure that this method of computation would have shown a much greater percentage of evaporation. I have read that a certain French physicist seemed to find a condition of mutual saturation existing between closely related elements such as these, and this may be the reason for the discrepancy. To present the results of our experiments in more striking form, I would say that they indicated that if an amount of gasoline sufficient to "carburet" the air in the hall in which this meeting is being held were kept in open vessels, or spilled upon the floor, it would be perfectly safe for persons to light matches and smoke, provided open flame was not brought into contact with any liquid gasoline. I have not tried this.

I note that one of Mr. Howard's illustrations is based on a pressure in the engine manifold of 0.5 atmosphere, which would be about 14¼-in. of mercury vacuum. We practically never have any trouble with vaporization at this vacuum and, under nearly all conditions of our observation, the manifold is substantially dry in such a vacuum. Where we have our trouble is at wide-open throttle, when the manifold pressure is nearly a full atmosphere.

One rather remarkable thing is that we apparently find that many engines show just as good power and fuel efficiency with the gasoline feeding to the cylinders as a stream along the walls of the manifold, as when the fuel is converted into a mist with a "hot-spot," under conditions of steady load and air speeds above 60 ft. per sec. *Cold manifolds fail under changes of speed and load,* and at temporary periods of driving where the air velocity falls below the limit already mentioned. We do find considerably less carbon deposit when the fuel goes to the cylinders in the form of a mist.

GEORGE M. BROWN:—So far as Mr. Howard's paper concerns the evaporation of fuel, I believe that it is very nearly correct. This opinion is based on more than seven years of experimental work in the interest of fuel efficiency. This time was spent entirely on the road, in traveling close to 100,000 miles under all conditions. I note no very appreciable difference in the evaporation possibilities of fuel today from that of 10 years ago, under my principles of usage.

Mr. Howard gives an equation representing evaporation in terms of time, surface and heat. To this he should have added what I might call "dispersion." Elementary physics teaches us that this is the effect of wind on evaporation, insuring an equalization of the vapor content per cubic inch of air, or an equal degree of saturation. My experiments have been based on the primary principle of a very large surface and very rapid dispersion which produces an effective evaporation and thoroughly equalized mixtures. This condition is attained through the carbureter instead of the manifold, thus insuring a mixture of equal richness in each cylinder, and depending simply on manifold design against wire-drawing in any particular cylinder, to prevent an inequality in volume.

From my long experience I believe that the solution of the fuel problem is based on surface and dispersion at initial contact, which is turbulence in the carbureter. My practical tests have proved that every possible benefit can accrue from this condition, as to both fuel economy and engine efficiency, with the minimum of complications.

In his answer to the fuel questionnaire, Mr. Horning states that he is studying turbulence as the most effective factor. After a close study of the application of turbulence in both ways, I do not know that it makes a great difference whether we start or end with this idea; but to start with it gets results by a simpler method and I believe that this reduces distribution difficulties. The two reports from Mr. Howard and Mr. Horning appear to be of marked value from a practical standpoint.

FRANK A. HOWARD:—In regard to the questions that were asked on the vapor tension of gasoline, it is quite true that the more gasoline there is the higher the vapor tension will be, within limits. The method by which that is met is to take the maximum vapor tension which can be obtained with a sample of adequate size and continue to add gasoline so long as the pressure shows any increase. In the case of the original gasoline, that is a very difficult matter because there is a small quantity of dissolved permanent gas in it. I suppose, if enough gasoline were added, the pressure could run up to equal that of the atmosphere. That criticism does not apply to vapor-tension determinations or distillation residues. That last 10 per cent can be regarded as a very nearly homogeneous compound. There is another way of checking it which is very good. The chemically pure hydrocarbons in the gasoline can be isolated and vapor-temperature determinations made on them.

As to the measurement of manifold temperatures, that wet-bulb thermometer effect is bothering many engineers. In my reference to manifold temperature I was talking about a dry mixture. I have no idea how to obtain a true indication on a wet mixture.

I said I did not know of any way of increasing the time element for vaporization. Mr. Nelson has already found a way for increasing it. This shows what the

progress in respect to hot-spot design is and what is possible in the way of juggling the three factors of surface, time and heat. Apparently we can handle all three of them now. None of them is excluded.

Mr. Brown raises the point that, in addition to the factors of time, surface and heat, the element of "dispersion" enters into volatilization. This is correct in the sense that the dispersion of the fuel vapors in the air must be great enough to give substantially a homogeneous mixture if the full inherent volatility of the fuel is to be utilized. It is theoretically possible that stratification or lack of homogeneity either in the intake pipe or in the engine cylinder might give the condition of a saturated stratum of air into which the fuel could no longer vaporize, and above this an unsaturated stratum. While the average volumetric content of fuel vapors in the charge would, therefore, be below the partial pressure of the fuel at that temperature, vaporization would be arrested until the process of diffusion equalized matters. True gaseous diffusion is, in itself, probably much too slow a process to be of value in carburetion and, while this is theoretically covered by the time element, turbulence therefore enters as a necessary practical factor for the utilization of full inherent volatility. This is not, of course, limited to cylinder turbulence, but includes turbulence in the carbureter and manifold as well.

President Vincent has directed our attention to the fact that the starting or warming-up problem is a very serious one which is often overlooked in discussions of the vaporization of fuel. There are many promising mechanical solutions of this trouble and I have no doubt these will be developed to meet perfectly the requirements for engines to be built in the future. With regard to existing engines, however, very little seems to have been done to help out on this matter. We have attacked it from the fuel standpoint by marketing at retail, with such wide distribution that we hope practically all motorists will be reached, a special high-volatility fuel which can be called a petroleum ether. The value of such a product for priming is, of course, well recognized. This particular product is so highly volatile that it readily forms an explosive mixture at a temperature as low as 72 deg. fahr. below zero, which is as low a temperature as we have been able to obtain in our own laboratories. There is being marketed with this priming ether a priming-cup, which can be mounted on the dash. This cup is in reality an elementary carbureter, having an air passage into which the priming ether is sprayed from a calibrated jet orifice. The capacity of the cup is sufficient to run an ordinary engine for about 35 sec. The device is operated as follows. The engine is started and run for about 500 revolutions on a fuel so volatile that low air and engine temperatures have no effect. This running period is long enough to warm the engine up fairly well. Of course, the better the hot-spot or heating device is, the more perfectly normal intake-pipe conditions will be established within this time. It is found in practice that this device can be operated without any particular skill. The regular throttle-valve is merely set in the idling position, the priming-cup filled and the engine started in the ordinary way, the choker-valve being wide-open. The richness of the mixture supplied by the primer is such that the dilution with air through the crack in the throttle-valve does not reduce it below firing proportions. Before the cup is exhausted, the engine will usually be warm enough so that the throttle can be opened fairly wide and the regular carbureter will come into operation without the use of the choker-valve. Here

again the leakage of air through the priming device is so small, with the throttle appreciably open, that the regular mixture of the carbureter is not reduced below explosive proportions. The primer, therefore, need not be shut off at the exact moment when its charge is exhausted, but should, of course, be shut off before the throttle is closed again.

This method of meeting the difficulty which President Vincent mentions has obvious disadvantages, but it does seem to afford a cheap and simple means for the ordinary motorist to obviate winter-starting and warming-up troubles.

A. C. FIELDNER:—It is truly astonishing that more attention is not paid to the composition of automobile exhaust-gases. I believe it would promote gasoline economy if manufacturers would install a gas-sampling connection in the exhaust pipe, between the muffler and the engine, and bring it up to some convenient place on the vehicle where a gas sample could be taken at any time. It certainly would pay large trucking companies to employ a chemist who would analyze the exhaust gas on motor trucks for the purpose of checking up carbureter adjustment.

MR. CHASE:—I have been very much interested in Mr. Fieldner's paper because on behalf of the Society I had something to do with suggesting the nature of the tests described. When the matter was broached several months ago, we placed particular emphasis on the desirability of conducting the tests under the actual conditions of service. I expected that the results would show exactly what they have shown; that the average car today is wasting, due to incomplete combustion, at least 25 per cent of the fuel that is fed through the carbureter. Not only does the engine run under the inherently inefficient condition imposed by throttling, but only 70 per cent of the total fuel fed is burnt. We sometimes criticize, with more or less justice, the oil companies for the quality of fuel that they furnish, but when a condition such as the one that has been shown by this paper to exist is present, it is certainly evident that there is much to be done by the automotive engineers and manufacturers as well as by the fuel producers.

C. A. FRENCH:—In the experiments described acetylene, sulphuric ether and carbon bisulphide were exploded in a closed cylinder of fixed volume. A glass window, running the entire length of the cylinder, was used to permit the making of photographs of the flame as it passed through the cylinder after having been ignited at one end. Such experiments are of great scientific interest and value, and these gentlemen should receive all possible encouragement to continue the work, particularly as combustion research has always been at a low ebb in this country. We should not, however, take these preliminary results as being necessarily indicative of anything that happens in the cylinder of an engine burning kerosene or gasoline, for the reason that the fuels used in the experiments are incapable of burning like paraffin hydrocarbons.

The first prerequisite of an unobjectionable flame for internal-combustion engines is that it be so blue, nonluminous, non-radiant and of such low actinic power, so that it is extremely difficult to photograph in the time interval available. Moreover, all of its characteristics are radically different from those of any luminous flame. In attempts to find the causes of our trouble with kerosene and gasoline, countless experiments in flame propagation, ignition temperatures and the like have been made, but in 99 out of 100 cases other fuels than kerosene

and gasoline have been used, the conditions under which kerosene and gasoline are burned were not stimulated, and the results obtained, while of scientific value, have not helped us materially in our problems.

A comparison of acetylene, sulphuric ether and carbon bisulphide with hydrocarbons of the paraffin series shows a great difference in their structure, compositions and characteristics. The ethanes, of which acetylene is the first member, have an empirical formula $C_n H_{2n-2}$ and all are unstable, unsaturated hydrocarbons. Acetylene gas has about the same weight as air; hence it diffuses slowly. In the formation of unsaturated hydrocarbons some of the carbon atoms, not being able to secure all of the hydrogen they would like to have, are compelled to form double, or sometimes triple, bonds with each other. Carbon atoms are always very reluctant to form these double or triple linkages between each other, it being necessary always to supply energy to force such a union. When these substances burn, they give off more heat than is indicated by the amount of carbon and hydrogen they contain. Such compounds are endothermic, that is, formed with a disappearance of heat, which is given off again when they dissociate. In the case of acetylene, this excess heat is about 23 per cent. Highly endothermic compounds of this kind are always unstable and may dissociate with explosive violence in the entire absence of air, oxygen or any other supporter of combustion. Under that condition, Berthelot and Vielle dissociated acetylene with a resulting pressure of 5638 atmospheres, after which the carbon was left as a solid lump with a brilliant surface. Explosive dissociation of compressed acetylene so frequently occurs spontaneously that all civilized countries prohibit its shipment or storage under pressure of more than 1 atmosphere, unless dissolved in acetone, or other solvent, and the solvent absorbed in a porous solid.

Except when used in special burners, it produces soot with mixtures of any ignitable proportions whether burned explosively or otherwise. The blue-flame period of acetylene burned explosively is extremely short and complete dissociation with more or less violence occurs at an early period, causing a halt in the oxidation, after which the free carbon and free hydrogen may or may not burn, according to circumstances. It is decomposed readily by heat, when it may completely dissociate, or it may polymerize into any one of a vast number of organic compounds. Thus we see that it is a highly endothermic, unstable gas, the flame characteristics of which are, except under most unusual circumstances, very different from those of the paraffin hydrocarbons.

Sulphuric or di-ethyl ether consists of an ethyl radical on each side of an oxygen atom; while the bonds of carbon to oxygen can be said to be fairly strong, nevertheless compounds containing them are often very reactive. Ether vapor allowed to flow through an expanding nozzle into an exhausted tube, 4 to 6 ft. long, turns its kinetic energy into heat on reaching the end of the tube and dissociates with considerable explosive violence. Any of the organic molecules having two similar radicals, bonded between them to an O, or to a ketonic oxygen CO, are prone to have unusual properties; the vapor tension of ether is characteristic of one of its radicals instead of the whole molecule, showing that the two radicals do not join forces to any considerable extent. This tendency of the radicals to act independently, that is characteristic of the ethers and at least some of the ketones, shows an anomalous bond that should warn us that these substances would, under certain circumstances, dissociate with considerable emphasis. We should expect about the same sort of a

ragged pressure line from the explosive combustion of ethers and some of the ketones that we get from the dissociation of the highly endothermic fuels.

The paraffin or saturated series of hydrocarbons have the empirical formula $C_n H_{2n+2}$. Their heat of formation being positive they are not under any stress and are therefore stable. From methane, CH_4, the first member, up to and including pentane, $C_5 H_{12}$, all members of the series could probably be burned explosively under as high compression as we would care to use in automotive engines, and they would never produce detonation or other objectionable effects, unless an excess were used. All periods of their flames would have a transparent blue color. At least it seems certain that neither detonation nor luminous flame could be produced in a homogeneous stoichiometrical mixture of air and paraffin series molecules, no molecules of which contained more than 12 atoms. Such a mixture should burn under any pressure or at any velocity with no undesirable effects. A stable hydrocarbon molecule of not more than 12 atoms has all of its atoms on the outside, or at least in communication with the outside, so that throughout combustion every fuel atom is being bombarded with oxygen molecules and atoms enough to burn them; under such circumstances oxidation will always take precedence over dissociation. There is no experimental evidence to show that detonation or knocking has ever occurred in an entirely blue flame of a paraffin hydrocarbon, or in ring compounds of not more than 12 atoms.

With a molecule as large as hexadecane, $C_{16} H_{34}$, the largest molecule usually found in kerosene, its size prevents more than 37 of its atoms having contact with oxygen; therefore the 13 inside atoms must wait for oxygen until the outer layer is burned away. If this burning takes place too rapidly, the oxygen cannot secure contact with the inside atoms of the fuel molecule until too late to save them from cracking. In all reason we would expect the 13 atoms of $C_4 H_9$ to be the end of the chain. As no such compound can exist, it would crack in the characteristic manner of the saturated series into one saturated and one unsaturated compound, which in this case would be ethane, $C_2 H_6$, and acetylene, $C_2 H_2$, and one lone hydrogen atom.

We should expect this kind of a combustion to halt when the 37 outside atoms were burned. The cracking and the formation of the acetylene would absorb some heat, and the acetylene would then dissociate with explosive violence; after this the free carbon, free hydrogen and the ethane would burn, making two and possibly three pressure peaks on the diagram. The flame begins blue, *as do the flames of all hydrocarbons*, and stays blue until the 37 atoms are burned away, after which it becomes brightly luminous, radiant and actinic. Practically always, an excess of fuel is followed by dissociation, even with small fuel molecules. A dissociation is always productive of the mixture. While a reasonable amount of ionization is necessary and desirable in combustion, an excessive amount can and does produce effects that are most undesirable. A luminous flame always denotes excessive dissociation.

It is important to remember that any kind of a flame of a common liquid hydrocarbon fuel cannot be propagated without an initial area or period of transparent blue flame in which the fuel and air are in explosive proportions. Entirely green, lavender, red, yellow or white flames cannot be propagated, nor can they be maintained if too widely separated from the blue flame. If a yellow flame is examined through a yellow color screen, it will

be found to be permeated by a thin blue flame and, if a supporting atmosphere is available, the yellow spot will be found to be entirely surrounded by blue flame. This is true also of flame spots of green, red and white, when each is examined through the proper color screen. In stable fuels green, red, yellow or white flame spots can be said to be the result of either temporary or permanent lack of oxygen. Thus, it appears that a transparent blue or lavender flame always indicates oxidation, while spots of any other color indicate either excessive cracking into new, smaller hydrocarbons, and the large production of CO, or the complete dissociation into free carbon and free hydrogen.

It will be found that if a given quantity of stable fuel is burned with an entirely blue flame, the flame occupies less space than when spots of any other color appear, provided too great an excess of air is not used. When a combustible mixture is of correct fuel-to-air ratio and the fuel is in the proper physical state, the resulting blue-flame combustion is much simpler, more complete and compact than any other. There is much evidence that carbon always burns immediately to CO_2, when it can secure the necessary air. In any event a normal blue-flame combustion will go to completion in less time and space than any other, thereby imparting all of its molecular forces to the gases early in the stroke and allowing a more complete expansion than is common.

It would not show any flame at the exhaust port. Only about 8 per cent of its energy is in the form of radiant heat, against 30 per cent or more in the luminous flame; it is incapable of making soot; and its progress is not affected seriously by contact with cold surfaces. As radiant heat has the same velocity as light, it is nearly 100 per cent loss in an engine cylinder; therefore it is the imperative duty of combustion engineers to devise a method by which present fuels can be burned with a blue flame.

Messrs. Woodbury, Lewis and Canby introduce experimental evidence which they believe shows autoignition of parts of the mixture ahead of the flame-front, which, under certain circumstances, is certainly possible. In the burning of rich mixtures of stable fuels and in the burning of unstable fuels in any fuel-to-air ratio, there is a great amount of dissociation from which an abundance of charged ions of every constituent of the mixture is produced. A pressure wave probably cannot be made to travel through molecular air in excess of the velocity of sound; however, there is nothing that prevents charged ions from greatly exceeding that rate. As spontaneous combustion can be started far below the ordinary ignition temperature of the fuel with oxygen ions and in many cases with hydrogen ions, there is no good reason for doubting that much of the so-called detonation or knocking arises from ignition of remote parts of the mixture by charged ions produced in the dissociation of the fuel. A reasonable degree of ionization of oxygen is of benefit in any combustion, but it should take place before combustion begins, as a sudden large production of ions during an explosive combustion is certain to produc undesirable results. This is another valid reason for the study and development of the blue flame in which dissociation is not a necessary event.

WILLIAM C. DAVIDS:—Has Mr. Fielder ever tried to heat the air between the carbureter and the engine, instead of heating it before it goes through the carbureter? I have found in practice that heating the air after the gas comes through the carbureter is far better than heating it before. Some years ago I experimented with hot-spots and used them in two-cycle engines carrying the hot-spot under the manifold and so heating it completely across. That heated the air and gas after it left the carbureter, and I think that is the proper way to apply the heat. The gas passing down into the crankcase of the two-cycle engine, receiving its heat from the pistons, was satisfactorily vaporized and we obtained exceptional efficiency from the engine.

MR. FIELDER:—We believe that heating the air between the carbureter and engine by the hot-spot method is undesirable because the temperature is uncontrollable due to the variations in the atmospheric temperature at different seasons of the year. This is a condition that we have tried to overcome. We all know that there are certain periods during the year when the average internal-combustion engine functions best, which is due to the atmospheric temperature being right, and we have tried to standardize this temperature throughout the year by use of the thermostat.

MR. SPERRY:—The fact is interesting that in the Diesel engine there is never any carbon monoxide to be found. I thought possibly that this might be a peculiarity of some work that we are doing and so sent our chemist to a Navy Yard where they are running Diesel engines of different sizes up to 700 hp. to analyze samples of exhaust gases. We now have analyzed many samples from engines running at 25, 50, 75 and 100 per cent of their rated load, and at 10-per cent overload. In none of those samples do we find the slightest trace of carbon monoxide. There is evidently some fuel saving there. In following out Mr. Chase's suggestion, if we are to compress the air, why not go somewhat further and produce auto-ignition, eliminating carbon monoxide entirely and at the same time rendering available a wide range of fuel and much cheaper fuel than gasoline.

I find that many engineers are afraid of high compression in an internal-combustion engine. Is it understood that, with the two or three rings that it seems wise to some engineers to add to get 500-lb. instead of 65-lb. compression, the piston will drop right through the cylinder of its own weight. There is no extra friction that amounts to anything and those pistons are coming out of long runs practically as good as when they started. Diesel engines are perfectly practical. There are thousands of them in operation. I venture to say that before this Hudson Vehicular Tunnel is complete we will have no carbon monoxide to cope with.

W. M. WALLACE:—I am indebted to Mr. Nelson for bringing to my attention the details of the results of his experiments with constant and variable-clearance aluminum pistons. The results of my own research to date, regarding this subject, indicate that the troubles with pistons are due basically to leakage around and under the rings and to lubrication difficulties. I doubt that joint leakage amounts to very much, compared with the leakage around and under the rings. Lubrication difficulties are accentuated in many instances by the apparent failure of designers to pay proper attention to the design insofar as lateral or wall pressures are concerned. There are also many other detail points, but these are not so important.

It is obvious that pistons should be as simple as is possible. The piston material preferably should have the same coefficient of expansion as, or less than, that of the cylinder material. Other views of the problem in certain cases, as in air service and in tractor and marine requirements where large and constant power is needed, indicate the necessity for some material capable of transmitting
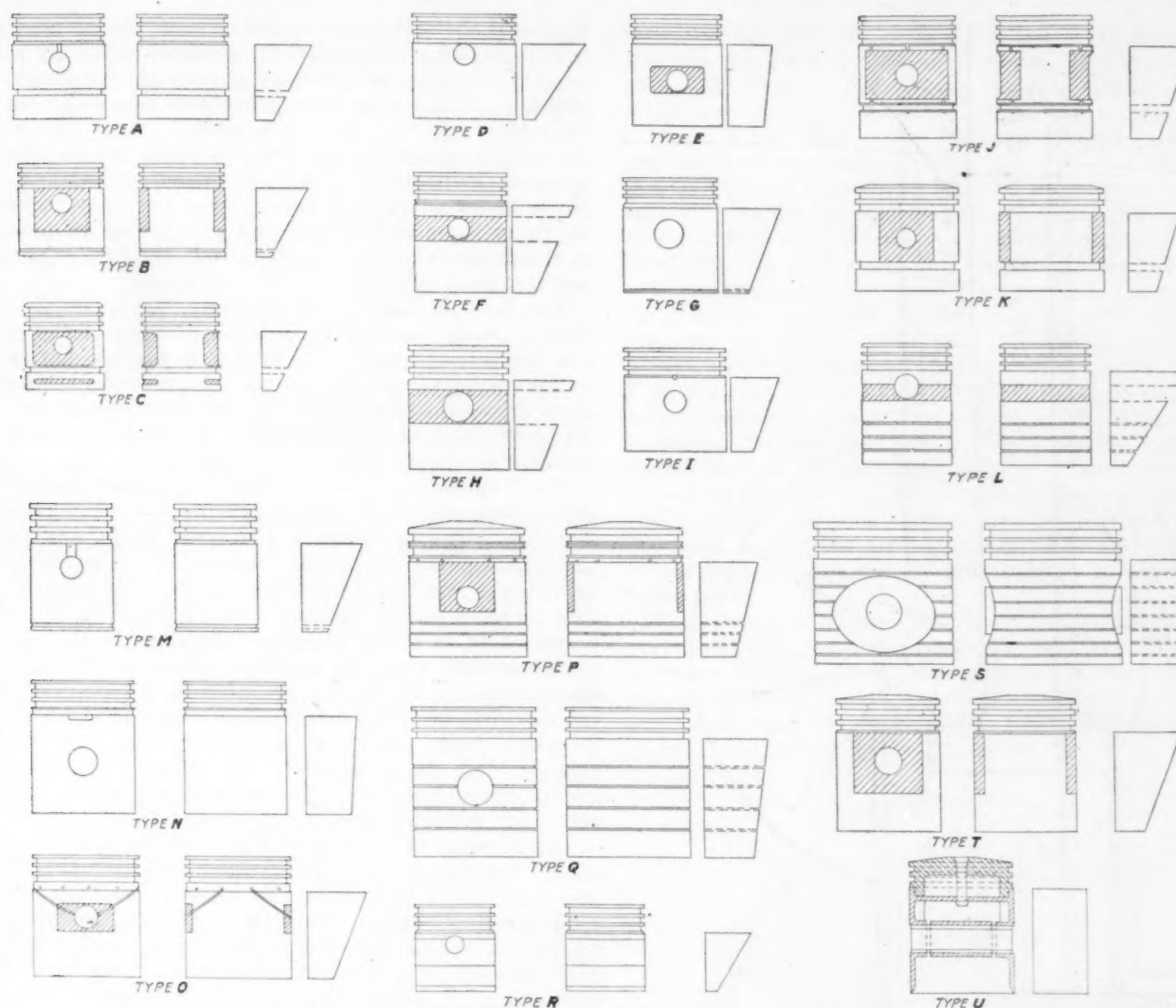
FIG. 5.—VARIOUS TYPES OF PISTON USED IN AMERICAN ENGINES

the heat quickly. To accomplish this alloys of aluminum usually are resorted to.

It seems that a false head of aluminum might be substituted for the more-or-less complicated and certainly more expensive type suggested by Mr. Nelson. It appears possible to attach such a false head by a single adequate fastening at its center, thus allowing the material to change form without distorting the light cast-iron shell, as is indicated for Type U, Fig. 5. With this exception the sketches shown in Fig. 5 are all taken at random from actual pistons of American-made engines. Some are old; some are more recent. They were assembled to show, so far as is practicable, the trend of practice regarding the provision for side-pressure. To make comparisons it was necessary to make a few assumptions, as follows:

(1) The thin surfaces above the bottom ring are neglected as bearing surfaces. This in most cases is certainly a fair assumption

(2) The material is considered rigid and not bending

(3) Friction of the piston against the cylinder wall and the wristpin bearing is omitted; these corrections are not only small but more-or-less self-compensating as the piston changes cycles

(4) The unit pressures indicated in the small sketches alongside of each type shown in Fig. 5 are obtained by the simple principle of the lever, assuming no bending, as mentioned in (2)

It seems logical that as a bearing crosshead Types E, K, N, P, Q and S would prove much better than the others. The remaining designs appear to predicate excessive wear above the pin, with a large margin of useless skirt. Inasmuch as the piston serves as the medium of converting the greatest amount of useful work from the combustion-chamber to the crankshaft, its tightness once and for all is imperative. Long service cannot be expected if the piston is eccentrically loaded as a bearing. Many engines are in use today with plain cast-iron pistons that have done years of yeoman service, but they were designed so that they wore very slowly in service and thereby maintained their efficiency. I believe that a reversion to plain light pistons which are accurately made and proportioned would in general be beneficial.

As regards the matter of reduction in weight of reciprocating parts, might it not be well to assure ample durability of the piston and cylinder wall, using such material and weight as may be necessary, and making such reduction as may be possible in the connecting-rods? Materials suitable for such forgings that are materially lighter than steel seem to show promise at this time.

Referring to the engine characteristics in connection with constant-speed driving, the interesting results indicate a geared fourth-speed. No doubt the excellent mileage claimed by many foreign makers is made possible by this fourth gear.
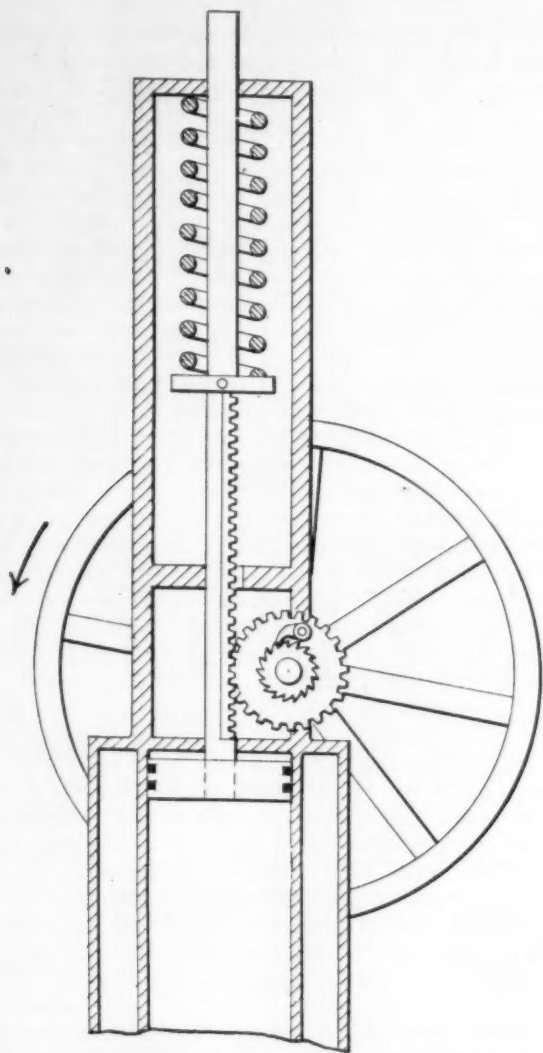
FIG. 6—A FOREIGN TYPE OF ENGINE IN WHICH THE HEIGHT TO WHICH THE PISTON IS THROWN BY THE IGNITION OF THE EXPLOSIVE MIXTURE IS REGULATED BY A SPRING WHICH ON THE RETURN STROKE DRIVES THE CRANKSHAFT THROUGH A RACK AND PINION

E. FAVARY:—It may be possible to eliminate the engine knock by mechanical means, and perhaps harness it or the indirect cause of it to increase the power derived from the products of combustion. According to indicator
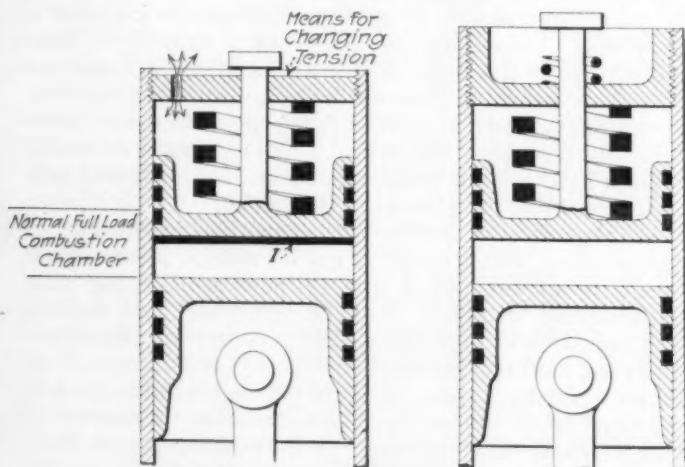
FIG. 7—SUGGESTED FORMS OF CONSTRUCTION FOR ELIMINATING KNOCKING IN AN ENGINE

diagrams there is a rise in pressure in the cylinder that is so high and so rapid that it causes a knock. By reducing the compression pressure somewhat, the knock disappears. The sudden rise in pressure takes place at the beginning of the expansion stroke, when the piston velocity is comparatively low. It seems to me that by using a cylinder-head or a combustion-chamber that yields under a pressure beyond that normally occurring in the cylinder at full load and just below the pressure at which knocking occurs, the knock could be eliminated and the mean effective pressure increased.

Fig. 6 is an illustration of an engine I saw in operation in Paris during 1897. Upon ignition of the explosive mixture the piston is thrown up as fast and as far as the spring will permit; on the return stroke the spring alone drives the crankshaft through the toothed rack and the gear wheel of the crankshaft. This engine, as I recall, had extremely high thermal efficiency.

Fig. 7 shows constructions that might prove useful for eliminating the knock and increasing the mean effective pressure. The drawings are diagrammatic, the valves and spark-plugs not being shown. This construction embodies a combustion-chamber of variable capacity so that under a partially closed throttle there is the same compression as under wide-open throttle. With a partly closed throttle, when the maximum pressure arising from the combustion of the charge is lower, the auxiliary piston descends until the maximum pressure in the cylinder is substantially the same as at wide-open throttle. In this manner the compression pressure is regulated by the maximum pressure. Several methods suggest themselves for reducing this system to practice.

The drawing at the left of Fig. 7 shows a small vent-hole in the top of the cylinder which will have the effect, in a measure, of preventing the upper piston from rising or descending rapidly. Instead of having the vent-hole where it is shown, the stem of the upper piston could be made to slide in a small sleeve having a vent-hole; this might be better adapted to regulating the speed at which the upper piston rises or descends. Making the upper piston heavy also would be found advantageous, on account of increased inertia effect. The spring can be located at the outside of the cylinder, instead of where it is shown, and it can be made to operate on the stem of such piston. Instead of using a spring, air might be compressed and caused to act like the spring. With this particular construction, suppose the piston were in a certain position at half-throttle, and that suddenly the throttle were opened wide, producing the condition under which knocking occurs. After two or three revolutions of the crankshaft the upper piston would rise by virtue of the increased pressure in the cylinder. This would not necessarily be due to the high pressure of the knock, but to the increased normal maximum pressure, until the knock disappears.

In the right-hand portion of Fig. 7 the upper end of the cylinder is entirely open or closed and the piston is made very light to reduce its inertia, so that at each firing of the charge it will rise at first. The upper piston can be made to begin to rise at say a pressure of 150 lb. per sq. in.; let us assume that the compression is just below that where self-ignition would occur. After the ignition of the charge the piston would begin its upward course and the knock might even assist to force it up. Then, as the power piston descends during the expansion of the gas, it will follow the latter piston for some distance and thus keep up the pressure at the beginning of the expansion stroke. After the upper piston stops the

expansion curve drops rapidly. The high pressure that is just below the pressure at which the knock occurs will increase the flame propagation from what it would be if the pressure were lower, and the expansion curve will therefore more nearly follow the adiabatic law.

Means can be provided for changing the tension of the spring in any convenient manner to vary the compression pressure. It possibly could be changed from the dash. This system will show a higher volumetric efficiency and the combustion-chamber will be smaller during the exhaust stroke; hence a smaller quantity of burned charge will remain in the cylinder. It may be possible even to expel substantially the entire burned charge by having the upper piston descend farther than is shown at the right of Fig. 7. On the suction stroke we should obtain a higher vacuum at the beginning of the stroke. This would fill the cylinder more thoroughly and the piston-heads could be insulated also, to decrease the thermal losses still further.

Instead of having the pressure in the cylinder raise the piston and having it stopped by a spring, mechanical means interconnected with the shaft might be employed which could be regulated so as to increase the volume of the combustion-chamber at the beginning of the expansion stroke or during any portion of any of the strokes. By having a high compression prior to ignition at all positions of the throttle, a very great saving in fuel might be obtained.

T. C. MENGES:—I wish to state the experience I have had in running stationary engines on kerosene. These engines are equipped with a throttling governor and a high-tension magneto and spark-plug. The difficulty with a kerosene engine is to get it to run well on a light load, or on no load. Fig. 8 illustrates the results of my experience.

First, the carbureter should be placed above the inlet valve. We have placed the carbureter below and on the side, but the best location is up above as shown. The reason is that if any liquid kerosene drops down, it is drawn into the engine and does not form a slug when the throttle opens up for a heavy load. Another reason is that kerosene vapor will not rise easily; it seems to be a heavier vapor than gasoline, and will stick to the walls of the manifold. If we put the carbureter above the inlet valve, we do not require as hot a manifold or as hot an intake of air. This gives better volumetric efficiency and the engine will run more satisfactorily. The carbureter on an automobile engine is usually placed below the manifold; consequently we have the same trouble in handling the lower grades of fuel that we had with the carbureter when it was located below the inlet valve.

Second, the inlet manifold should be short. A manifold like that in Fig. 8 gives good results. In a long manifold unless the manifold is kept very hot, the kerosene vapor will condense and form a poor mixture. Curves and turns in a manifold should be avoided. No extra heating of the mixture is necessary when the manifold is short. It seems that if we can get the fuel vapor into the cylinder without condensation, the engine will run well. We are able to run engines on kerosene without a hot-air manifold, and we do not need to use water to keep down the knocks. This probably is due to the fact that the vapor enters the engine in a fairly cool condition.

Third, the most important point is the location of the fuel nozzle. All automobile-engine carbureters seem to have the nozzle in the center and separated a long distance from the butterfly throttle-valve. This is all wrong for utilizing kerosene, and I believe it is wrong for utilizing the lower grades of gasoline. In Fig. 8 it will be noticed that the nozzle is in the side of the air-pipe. What is of greater importance is that it is located within 1/16 in. of the edge of the butterfly throttle-valve. We have tried all different locations and none of them works so well as the one shown in Fig. 8. The nozzle should be very close to the throttle, but this is impossible with the ordinary type of carbureter. If the fuel nozzle is located as shown, the engine will run well at any load or speed.

When the engine is running on no load, the butterfly throttle-valve is almost closed, and what little air passes into the carbureter must pass the fuel nozzle. This breaks up the liquid fuel and forms an explosive mixture. I believe that if the liquid kerosene could be broken up into a fine enough mist, an engine would start cold on kerosene. On the other hand, if the kerosene is not thoroughly broken up, an excess amount of heat will be required to vaporize it. One should be sure to locate the fuel nozzle on the side which forms the bottom sweep of the turn, so that the air does not need to hold the liquid in suspension, as would be necessary if it were on the upper side.

The substance of my experience in running stationary engines is that the three important features in utilizing kerosene fuel are (a) to locate the carbureter above the inlet valve of the engine, (b) to use a short manifold with few bends, and (c) to place the fuel nozzle next to the edge of the butterfly throttle-valve.
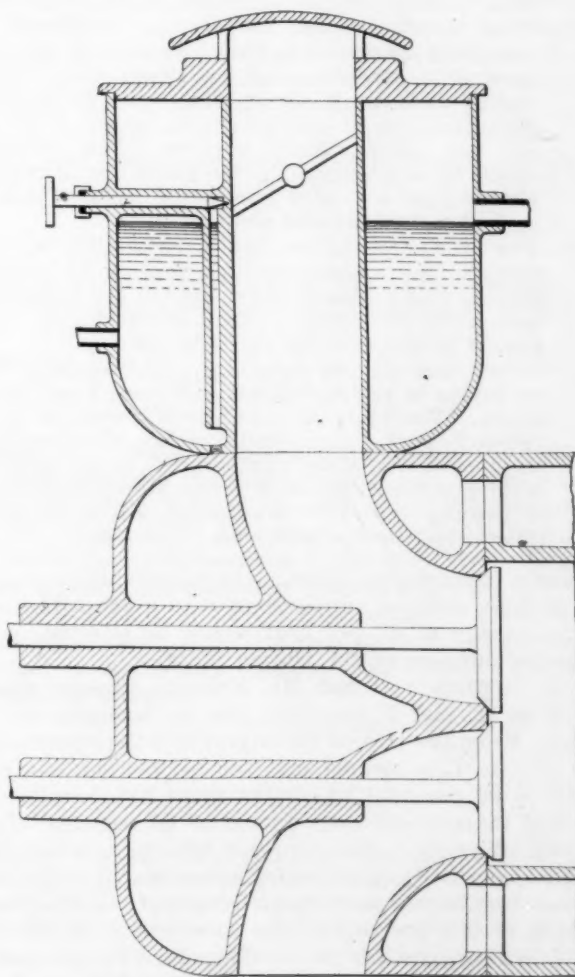

FIG. 8—SECTIONAL VIEW OF A PORTION OF A STATIONARY ENGINE DESIGNED TO BURN KEROSENE

G. Hamilton Grapes:—In reference to the fuel problem, the following improvements are needed to afford free growth to automotive plants and national production.

(1) A halt to further dilution of standard gasoline by fractions having end-points above 400 deg. fahr.

(2) The addition to standard gasoline of 10 per cent of benzol or 20 per cent of alcohol, or proportions of both

(3) The raising of all engine compressions by 10 per cent

(4) The employment of smaller and more efficient engines, and the lightening of chassis and bodies. All of this would represent a probable further 10-per cent increase in fuel efficiency and conservation

(5) The absolute gasification of the higher-boiling fractions, and the maintenance within minimum limits at maximum efficiency, by suitable automatic apparatus, of the temperature of the gaseous mixture prior to its entry into the engine cylinders. This would prevent the present waste of 10 per cent of standard gasoline now so evident in the excess of carbon monoxide and dioxide products in city service, in the dilution and deterioration of engine lubricants and in carbon deposits throughout the explosion chambers and in the gas exit passages of internal-combustion powerplants

(6) That the oil companies are best fitted by their organization to place economically upon the market a standard power fuel compounded with alcohol at a controlled price limit. Their cordial cooperation and coordination with the Society of Automotive Engineers in its efforts to solve this problem are most desirable, in the best interests of the public

(7) That the Government should install forthwith a laboratory, personnel and equipment to be entirely devoted to research work in compounded liquid fuels. This work should deal with constituent parts including alcohol, petroleum, benzol, shale oil and any other suitable medium. This activity should be supplemented by the production of power alcohol upon a limited commercial basis by State agricultural experiment stations

(8) The prohibition by the health authorities of the present fuel wastage by the emission of excess noxious gases by any motor vehicle, the result of incomplete combustion. This should be on the ground of danger to the public health

(9) A tax upon all cars weighing more than 2000 lb., or having a seating capacity of more than four adults. The proceeds should be allocated to fuel research work. This should reduce considerably the present loss in the transportation of non-profit-earning tare-weight which is now a fruitful source of gasoline wastage. If enforced, this tax would effect a fuel saving of at least 5 per cent

Upon a conservative basis, it is reasonable to suppose that if these outlined suggestions were given a thorough trial, a saving of 40 per cent would be effected in the liquid-fuel supplies of the United States.

H. L. Horning:—I had Mr. Nelson's advance experimental notes, and I examined the performance of the engine. From the size of the engine and the compression ratio of 5 to 1, it seemed that the combustion efficiency should be 66 per cent or, in the more usual terms, the indicated thermal efficiency should be 66 per cent of the air-cycle efficiency. The air-cycle efficiency, which is a standard by which engine performance can be judged and is based on a fundamental characteristic of an ideal working fluid, is 47.5 per cent of the total energy in the fuel for a 5 to 1 compression ratio. Therefore, 66 per cent of this would be 31.3, which is the indicated thermal efficiency. On examination of Mr. Nelson's results I found

that he attained this efficiency at 2100 r.p.m., the speed at which the gas velocity through the intake valve usually produces the highest thermal efficiency in overhead-valve cylinders. He started out to accomplish the elimination of the knock, the highest horsepower performance and the greatest possible ton-miles per gallon of fuel, in an engine. Mr. Nelson is to be congratulated on having practically accomplished these three results on his given product.

The lesson we can draw from his results is that by using a much smaller engine and thus limiting the horsepower still greater results in useful work can be accomplished. This is not a criticism of his paper; it is making the most of the information and conclusions undoubtedly indicated by the paper. In examining the curve of indicated thermal efficiency at speeds of 1000 to 1400 r.p.m., it will be noted that it rises very rapidly. This indicates that the turbulence at these speeds is very low, and it is not until the engine attains 2100 r.p.m. that we reach the highest efficiency. At the speeds just below 2100 r.p.m. however the curve of the indicated thermal efficiency rises with comparative rapidity and exceeds a 3-per cent range in 600 r.p.m. This indicates that the combustion efficiency has been neglected for volumetric efficiency. A lower-lift valve would have given a higher gas velocity and a greater efficiency at lower speeds, without sacrificing the volumetric efficiency in a marked degree and therefore sacrificing the horsepower. Mr. Nelson was able to get down to 0.51 lb. per b.hp-hr., which is a very credible performance, but it is possible for him to attain a fuel consumption of 0.48 lb. per b.hp-hr. by increasing the combustion efficiency as suggested.

Mr. Nelson:—Mr. Horning has carefully studied my paper and offered some very constructive criticism. The best performance of the engine does not come at full load; it comes at about 90 to 95 per cent of the full load. Under those conditions the economy will equal that of Mr. Horning's expectations. I have tried 0.375-in. valve-lift. The loss of maximum power is slight. A close comparison of results along Mr. Horning's line of suggestion has not been made, but it should prove very interesting. The striking feature of Mr. Horning's work is his ability to determine with great accuracy the results that should be obtained. It is clear to me that his work on turbulence is bearing fruit.

Mr. Horning:—In reference to Mr. Fieldner's paper, as liquid fuels have increased in end-point or decreased in volatility, a number of difficulties have developed in the operation of engines which are familiar to all. Among them are

(1) Difficulty of starting at low atmospheric temperatures

(2) Poor acceleration immediately after starting, particularly in cold weather

(3) Low miles-per-gallon performance

(4) Rapid deposits of carbon on the combustion-chamber walls

(5) Rapid wear of rings, piston-ring grooves and cylinder walls, due to diluted lubricating oil on the cylinder wall

(6) Dilution of the crankcase oil with the heavier constituents of the fuel and products of combustion

(7) High consumption of lubricating oil, due to a thinning of the oil by the fuel

These are the common forms of complaint and difficulties that are experienced with modern fuels. There are other ways in which the performance of the engine is affected. These need not be discussed at this moment.

An analysis of all these results indicates that they arise largely from the incomplete vaporization of the fuel in time to be of value in producing power.

Outside of the tendency of the great bulk of the fuel available in the world to cause knocking in the engines and thus limit the power available from these fuels, namely the paraffines and olefines, the problem of vaporization is the most important one from the standpoint of conservation which confronts the engineer. It is therefore interesting to consider how the efficiency of vaporization can be ascertained. The indicated thermal efficiency of any engine is the percentage of the total energy of the fuel left after deducting the losses due to volumetric considerations and the loss of effective gaseous fuel due to poor vaporization. Carburetion efficiency is the ratio of the fuel actually burned to that supplied, or the ratio of the energy found in the indicated mean effective pressure to the energy which should be found in the mean effective pressure if all the fuel were burned. A way by which carburetion efficiency can be ascertained is testing an engine with a very volatile fuel, one which approaches as nearly as possible the form of fixed gases at practical temperatures. The most convenient fuels to use for this purpose are the better grades known as "aviation gasolines"; the standard test fuel should contain enough of the napthenes and aromatics to remove the possibility of detonation, auto-ignition or preignition. The procedure is to make a test of engines at the various speeds and loads with these better gasolines, finding the indicated thermal efficiency attainable under these various conditions. By dividing the indicated thermal efficiency by the air-cycle efficiency, the relative efficiency, which can be considered as a combustion efficiency, is ascertained. In this combustion efficiency we have a standard by which we can judge the performance of any engine and any fuel. The use of this standard is indicated by the following fundamental statement.

There is a limited range of air-to-fuel ratio by weight which can be fired in an engine. This varies from 8 to 1 to 18.75 to 1. With a fuel having a B.t.u. content of approximately 19,400 per lb., a mixture of perfect proportions has a ratio of 15 to 1. The maximum heat that it is possible to liberate is controlled by the oxygen present in the mixture. With a mixture having less fuel than the amount demanded by perfect chemical proportions, the amount of heat liberated is measured by the amount of fuel present. It is obvious, therefore, that the amount of heat liberated in any mixture, from the leanest that can be fired up to the chemically perfect mixture, is proportional to the fuel content of the mixture. Because any fuel over the amount necessary to consume all the oxygen cannot burn, this excess is of no value in producing heat and merely acts as a diluent, the same as an excess of air acts as a diluent. Since 1 lb. of air at normal temperature and pressure has a volume of 13 cu. ft., and it takes 15 lb. of air to burn 1 lb. of fuel, 195 cu. ft. of air is required for 1 lb. of fuel. Therefore, in 1 cu. ft. of mixture there are 19,400/195 or 100 B.t.u. Considering the cylinder to have a volume of 1 cu. ft., and the piston an area of 1 sq. ft., on the assumption of no losses, we would have the following thermodynamic relationship:

$$PV = W = FS$$

where

P = average pressure in pounds per square inch
V = volume range in cubic feet of mixture
W = work done in foot-pounds
F = average force in pounds
S = space range in feet
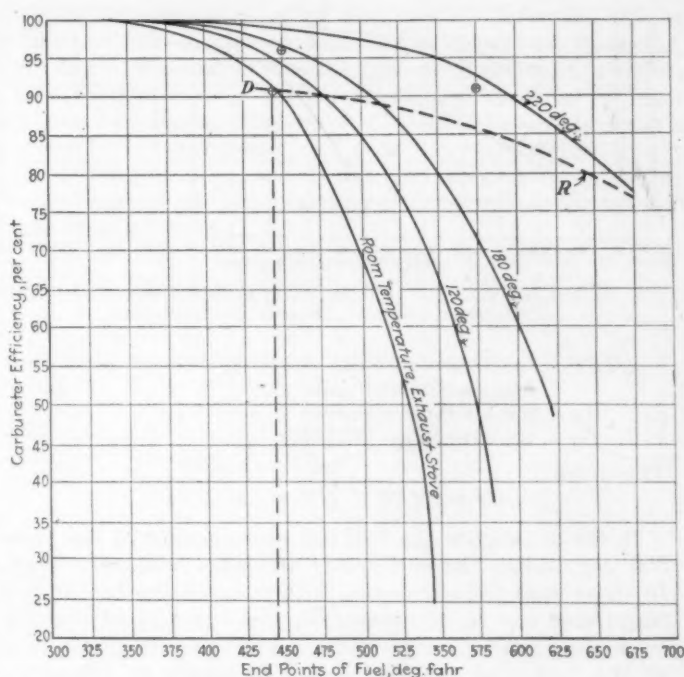
FIG. 9—CURVES SHOWING THE RELATION BETWEEN CARBURETER EFFICIENCY AND THE END-POINT OF THE FUEL

Thus in 1 cu. ft. of mixture we have as indicated above 100 B.t.u. If we multiply this by the constant 778 ft-lb. per B.t.u., we have the total number of foot-pounds of energy in 1 cu. ft. of standard mixture. If we divide this by the number of cubic feet, we have the number of pounds per square foot and, since there are 144 sq. in. in 1 sq. ft., we can thus derive the number of pounds per square inch by dividing the number of pounds per square foot by 144, or

$$P = E \div (144 \times 1)$$

where

P = the average pressure in pounds per square inch
E = the energy content of 1 cu. ft. of the correct mixture

Hence

$$P = 77,800 \div (144 \times 1)$$
$$= 45$$

Since the amount of mixture drawn into the cylinder is always less than the swept volume, due to the restriction of the intake valve, the manifold and the carbureter, and the temperature, the pressure obtainable would be reduced to that corresponding to the volumetric efficiency. If we calculate the indicated thermal efficiency from the air-cycle efficiency by using the combustion efficiency attained when using a perfect fuel as indicated above, we will find, with the less volatile fuels, that the following relationship obtains:

$$ITec \times E \times V > IMEP$$

or

$$Ae \times Ge = ITec$$

where

$ITec$ = the calculated indicated thermal efficiency
E = the number of British thermal units per cubic foot multiplied by 778 and divided by 144
V = the volumetric efficiency ascertained by measuring the weight, at standard temperature and pressure, of the air actually used, and dividing this by the swept volume of the engine
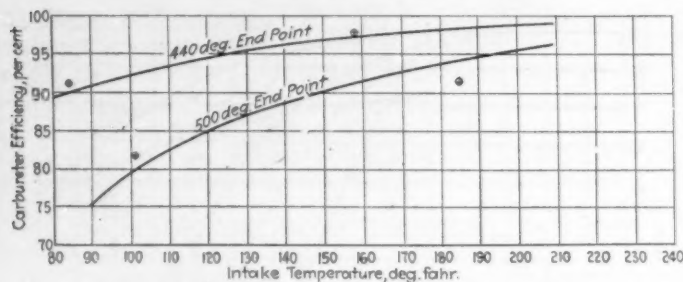
FIG. 10—CURVES SHOWING THE RELATION BETWEEN THE CARBURETER
EFFICIENCY AND THE INTAKE TEMPERATURE

IMEP = the indicated mean effective pressure actually
attained in the engine
Ae = the air-cycle efficiency
Ge = the carbureter efficiency

Therefore

$$Ge = IMEP \div (ITec \times E \times V)$$

In the days when the fuel had an end-point of less than
300 deg. fahr., the carbureter efficiency was very high.
In those days the accidental heat given to the fuel in the
carbureter and by the manifold, and the heat of the air,
or in the cylinder, was sufficient to evaporate practically
all the fuel. As the fuel began to recede in volatility,
300 deg. fahr. being the approximate initial point of kero-
sene, the manifold became more important as a means
of supplying the heat essential for vaporization, and it
was found necessary to heat the air to insure vaporiza-
tion. With the next decrease in the volatility of the fuel,
it became necessary to heat the manifold; and a consid-
erable amount of the fuel was evaporated inside of the
cylinder. On still further decrease in the volatility of
the fuel, the manifold temperature assumed still greater
importance and the cylinder reached the limit of its abil-
ity to evaporate the liquid fuel entering it, in time for
effective combustion. With kerosene as fuel, the highest
temperatures of the manifold and the cylinder practical
in operation are necessary for reasonable carburetion ef-

I to A - First Acceleration
A to B - First Uniform Velocity
B to C - Second Acceleration
C to D - Second Uniform Velocity Known as Detonation
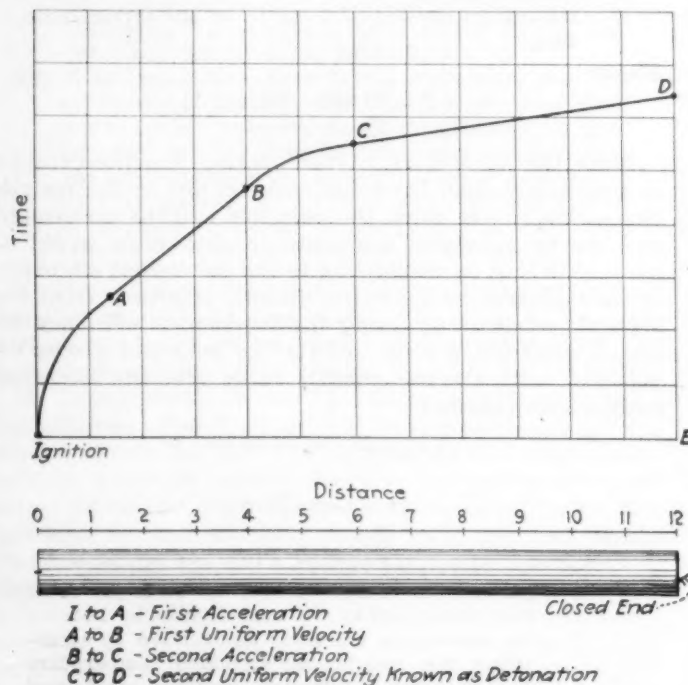
Closed End

FIG. 11—DIAGRAM SHOWING THE VARIOUS STAGES IN FLAME PROPA-
GATION IN A TUBE HAVING A CLOSED END

ficiency. The fundamental consideration in the designa-
tion "carburetion efficiency" is that the function of the
carbureter as originally intended to vaporize the fuel as
well as meter it has been spread from time to time toward
the piston of the engine. Therefore, while the carbureter
is not now performing the function of vaporization, other
elements in the engine are pressed into service to accom-
plish this result. It is thought proper to call the effi-
ciency of vaporization "carburetion efficiency." The let-
ter *G* is used to denote the fundamental necessity of hav-
ing the fuel in the form of a gas. We can assume that
the cause of low thermal efficiency in modern engines
burning the heavier fuels at compression ratios below
that of detonation, is due to low carburetion efficiency.

Notwithstanding that the temperature of the ingoing
mixture is only approximately an index of its condition,
this index gives us a basis on which to chart the efficiency
of vaporizing systems on modern engines. Since it is the
index of the atomization of the fuel at the nozzle of the
carbureter and the vaporization in the intake manifold,
it is a fair basis of judgment of different systems of va-
porizing. Since the end-point of various fuels is asso-
ciated with that proportion of fuel which resists vapori-
zation, this can be taken as an indication of the fuel value
from a vaporization standpoint. If we take an engine or
a series of engines with different kinds of carbureters
and vaporizing systems and list them with respect to
the temperature of the ingoing charge, we have a basis
for testing one of the fuels available. Testing this fuel,
we will find that, as the intake temperature increases,
the carburetion efficiency also increases within limits. If
we take a number of fuels having increasing end-points,
and plot the results of these different fuels with different
systems, we will have a complete graph of the effect of
different systems of vaporizing with fuels of different
end-points on carburetion efficiency (See Figs. 9 and 10).

In Fig. 9 the point *D* on the room-temperature exhaust-
stove curve, denoting the system used on the Ford, is a
very interesting point and of equal importance to the
automotive and the petroleum industries. This point is
the end-point of the standard gasoline according to the
present Government specifications, and happens to be at
such a place on the curve that a 10-per cent increase in
the end-point will represent a 10-per cent decrease in the
carburetion efficiency. The result is that there would be
no economic gain, inasmuch as there would be no power
delivered for the additional fuel bought or supplied. By
running the line of 440-deg. end-points vertically through
the other curves, we have the 440-deg. end-point curve
of Fig. 10 which, interpreted, means that for any further
increase in end-point there will have to be a correspond-
ing increase in the intake temperature. If, in Fig. 9,
we investigate the curve of 180 and 220-deg. intake tem-
peratures, we will get a curve ending in *R*. This curve
is what is known to economists as the "curve of diminish-
ing returns." The line shown is for full load and at
1000 r.p.m. and, since the carburetion efficiency is highest
at full load and higher speeds, this *D-R* line represents
the maximum attainable. Ascertaining the *D-R* line for
various loads and speeds would give all the vaporization
data necessary and when determined from actual condi-
tions would be of immense value. I submit that this is
exactly what the automotive and the petroleum indus-
tries desire to know. Perhaps the public desires to know
it more than anyone else.

I submit that this is the curve which should be the
object of our immediate research efforts. It is the com-
mon ground on which the industries involved and the

public can measure their exact position. It is the only curve by which designers of automotive apparatus can direct their efforts, as well as the only curve by which the petroleum industry can tell whether additions of heavy fuel are of any value to the public when used in the apparatus available. A meeting of the Joint Committee of the Petroleum and Automotive Industries, the Bureau of Standards, the Bureau of Mines and the Society of Automotive Engineers unanimously approved a program of fuel research to be supported by these agencies of which Figs. 9 and 10 illustrate a skeleton representation of procedure and objective. It seems certain that the most urgent immediate research is the efficiency of vaporizing systems with respect to the increased specific gravity of fuels.

With respect to the problem of applying the theories of flame propagation to the phenomena which occur in the cylinders, the following is a theory that our company has developed and used in research work. Referring to Fig. 11, *I-E* is a pipe in which a combustible mixture is ignited at the point *I*. As flame travels along the pipe toward the end *E*, the velocities change according to the order hereinafter described. An examination of a large number of flame photographs indicates that there are four possible phases in the velocities of the flame in a tube of uniform cross-section, not all of which are apparent, but which are approximated in nearly all mixtures. The four phases through which the velocities pass are as follows: As the flame travels from *I* to *A* it accelerates; this period is known as "the period of first acceleration." As the flame travels from *A* to *B*, it takes a uniform velocity. This phase is known as "the first phase of uniform velocity." As the flame travels from *B* to *C*, it passes through its second acceleration, and is so known. As the flame travels from *C* to *D*, it attains a uniform velocity and continues at this rate, which is known as "detonation." The use of a tube in the study of flame propagation is merely a device for drawing out the process of ignition, and for developing these four phases of flame velocity. The tube tends to establish the condition of quiescence and thus remove such artificial physical factors as stimulate the rate of reaction outside the condition of temperature and pressure. Since the flame travels into an entirely fresh mixture undiluted by products of combustion, the mixture is successively subjected to a rapidly increasing condition of temperature and pressure restrained by constant area of the flame crest, the chemical stability of fuel and dissociation.

However, it seems probable that with all hydrocarbon fuels, after a certain velocity of flame is reached, the catalytic action of the hydrogen ion has a decided influence on the rate of flame propagation, and it is entirely probable that an incandescent particle of glass may initiate some of the changes in velocity. Sound-waves traveling through the mixture tend to add compression effects and they can be seen traversing the regions of partial combustion, causing increased brilliancy of flame, and thus can be considered as augmenting combustion. Whatever phenomena may exhibit themselves in the idiosyncrasies of flame velocities can be considered as the resultants of all these factors.

For the practical man, we can set forth some seeming certainties based on thermo-chemistry. The region *B-C* represents a condition of combustion which, if it were possible to attain homogeneity throughout the mixture, would produce the highest thermal efficiency. The successive stages of *C-D* represent an increasing presence of too rapid a combustion of some of the contents, with the resultant incandescence of solid carbon particles. These represent an increasing loss due to direct radiation and, no doubt, the heat affects the regions of unburnt mixtures and accounts for a rapidly increasing reaction in these regions of flame. The point *C* also is favorable from a dissociation standpoint and may therefore symbolize the best compromise in practice between the controlling chemical and physical factors with respect to the highest thermal efficiency.

Phase *A-B* can be considered as the rapidity of combustion corresponding to lean mixtures and low loads
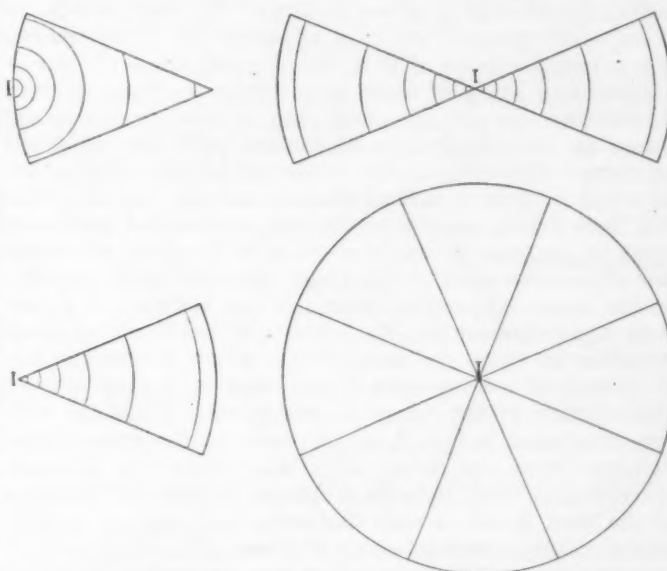
Fig. 12—Diagram Showing the Increase in the Area of the Flame Crest in Different Forms of Combustion-Chamber

and, from a thermodynamic standpoint, is characterized by a smooth sweet running of the engine.

Phase *B-C* can be considered to represent the combustion of the most economical mixtures at loads at and under that giving maximum economy, provided there is no marked or incipient auto-ignition. This is at nearly full-load performance and with lean mixture of low-compression engines down to normal running. This performance is not characterized by any roughness.

Phase *C-D* is characteristic of the engine having a compression just low enough to avoid detonation at the most economical mixture, but which is running with a richer mixture. This may also be representative of an engine running when the ratio is somewhat too high for available fuels; running at full throttle either accelerating or at full load. The action corresponding with this is a very rough performance and the effects can easily be felt as well as heard.

Phase *D-E* is one represented by the very rough performance of an engine in which the compression ratio is too high for the fuel available, the engine running at full load on a perfect mixture, and is about as rough as can be imagined. The roughness is greatest at a speed of maximum torque, which is at relatively slow speed.

The first phase is one in which the flame is of a blue color. The second phase increases in intensity of color and sometimes approaches green, and this is the very best and most efficient type of combustion. The third phase is one in which a yellow color is emitted from the flame, and the fourth one in which the flame has a brilliant white appearance.

A tube has the limiting feature of a small uniform

cross-section and it therefore is obvious that the only way in which a given volume of explosive mixture can be consumed in a relatively short time is by the use of a high velocity of the flame crest. Inasmuch as the efficiency of combustion is represented by the velocities not exceeding C, the problem of combustion in an internal-combustion engine resolves itself into a resort to other means of increasing volume consumption than by flame velocity. The theory used and developed by us is the theory of maximum areas. This involves the simple geometrical fact that a volume is generated by an area sweeping through a given distance. In other words, in a quiescent mixture the most effective way of consuming the greatest volume of it in the shortest space of time is to provide a shape of chamber in which the flame surface or crest can spread out, developing at each successive advance an increasing area of contact with the unburned mixture. Referring to the upper left portion of Fig. 12, in which we have a conical-shaped chamber and in which the lines drawn are the successive positions of the flame crest at uniform intervals of time in the form of chamber shown the area of the crest decreases very rapidly. In the lower left corner, with ignition starting at I and with lines representing the advance of the flame in equal divisions of time, we have a form which favors the development of a large area of the crest with each successive advance of the flame. It can be shown that the volume consumed in this form increases as the cube of the distance from the firing point and, since the distance traveled may vary in some mixtures roughly as the cube of the time, it will be seen that great volumes can be consumed in very short intervals of time. This high rate of volume consumption is based on the assumption that the flame is traveling into unburned mixtures and does not take dissociation or dilution into consideration. If we make a figure of two cones, starting the ignition at the peak as shown, the flame will then travel out as indicated and we will therefore have consumed twice the volume of mixture in the same length of time. If we generate a sphere with a great number of cones and ignite the mixture at I at the center, we will consume the greatest possible volume in the given time. It has been found by tests of explosive mixtures in vessels having approximately the form of a sphere that the rapidity of rise in pressure is maximum when the mixture is fired at the center, and at a minimum when the mixture is fired at one side. All these considerations have been based on a quiescent mixture.

The next expedient which suggests itself is that of furnishing many points of ignition. This again affords a means whereby great volumes of explosive mixtures can be fired without reaching high unit velocities of the flame at any point of the mixture. Thus, the diagram in the lower right-hand corner of Fig. 12 can be conceived to be a sphere of very small diameter and with many ignition points, we have many spheres merging into each other.

The other means available for increasing the volume of explosive mixtures consumed in a given time is stirring up the mixture and producing in it what is known as turbulence. If we produce a rapid enough circulation of the gases, it is possible by igniting them at the point of greatest rapidity of movement to approach approximately the effect of a multitude of ignition points. With this large number of ignition points distributed throughout the mixture, it is possible to initiate numerous spheres of flame and therefore an infinite number of small veloc-

ities and rapidly increasing flame areas and hence the maximum volumes in a unit of time without approaching the flame velocities of detonation. There are other considerations such as the area-volume ratio and the fact that spark-plugs have to be situated at the outside of a sphere. These need not be discussed here, other than to call attention to the fact that, because of the cool layer of gas on the walls of a combustion-chamber, turbulence insures a larger volume of gas consumed in a given time by driving the surface gas off into the flame and thus replacing it with the burned products of combustion. In a sphere the relative volume of these layers is minimized.

The process of turbulence is merely a physical assistance to the process of chemical reaction by assisting the kinetic tendencies of one species of molecules to make contact with those other species with which they must unite under the conditions in the cylinder. The process of chemical reaction of which combustion is one type is a surface phenomenon. The most modern conception of the constituents of the atom is that the electrons in the outside layer are the ones which give the atom of molecule its chemical properties. Therefore, when we develop the maximum of flame-swept volume by adopting those shapes of combustion chamber which will allow the most rapid development of flame-crest area for both mixtures of a relatively quiet nature and those aided by turbulence, we follow the most fundamental law of chemistry. In very slow combustions the reaction of hydrocarbons is in very many steps; as the reaction increases in rapidity the chemical stages through which a unit volume of mixtures pass become more direct, and it seems from all known considerations that the most thorough and best-controlled combustions are those in which the combustion-chamber can be considered to be filled with a mixture comprising a large number of small volumes in which the initial and end-stages of combustion are occurring at one time, intermingled with the products of combustion and their dissociations. There should, therefore, be a general homogeniety throughout the mixture rather than a progressive change of reaction from one part of the mixture to the other. The ideal condition would be that in which the various reactions going on in any small unit section at any one time are typical of those in a section of similar size in any part of the mixture. This is the very antithesis of the conditions in a tube.

There are three kinds of knock which are vaguely understood

(1) The knock which comes by igniting the charge too soon, and this can be produced either by the ignition system of the engine or by some hot-spot in the combustion-chamber

(2) The knock caused by pure detonation or, in other words, what occurs when an engine is running very slowly and the flame traveling in a mixture that is approximately quiescent

(3) The knock produced by auto-ignition, due to the shape of the combustion-chamber with a slow-burning mixture in which a virtual pocket of unburned gases fails to burn by the time maximum temperatures are reached; or, due to fuel left over at the high-temperature point, because of slow-burning mixtures; or, due to a two-stage combustion or a combination of all three of the above causes.

I know of no chemical reaction which turbulence does not assist in such an orderly way as to control materially the causes of knock listed above.

Aeronautic Propeller Design

By F. W. CALDWELL[1]

Illustrated with CHARTS AND DRAWINGS

THE tendency of propeller design in the United States, France and Germany has been toward very narrow blades with extremely narrow tips. The British have adopted narrow tips but have not gone as far in making the main portion of the blade narrow with respect to the diameter. The use of these blades has been arrived at principally by the method of trial and
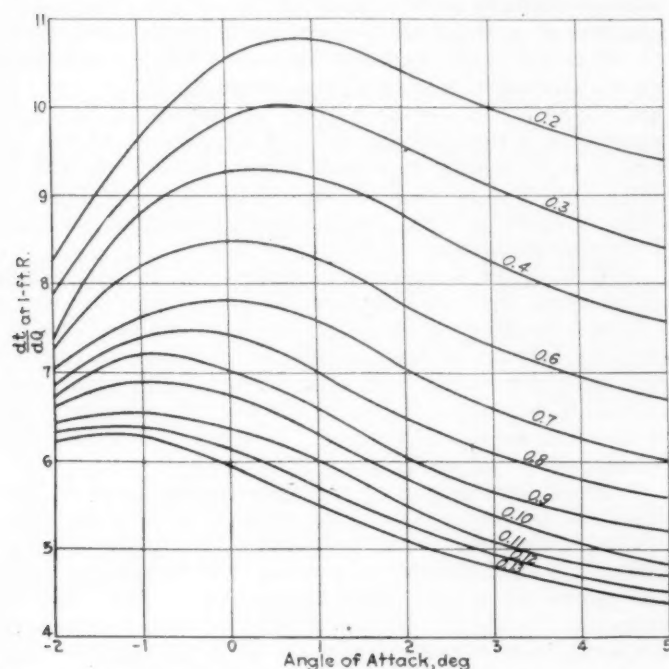

FIG. 1—OPTIMUM ANGLE OF ATTACK FOR VARIOUS BREADTH RATIOS FOR A SECTION HAVING A CAMBER OF 0.09

error; experience having demonstrated that such blades give better performance in climbing and at top speed. The inflow theory, however, gives an indication that it is better with fast turning low-pitch propellers to use a somewhat narrower blade than has been customary on account of the fact that the optimum angle of attack for the various stations approaches more nearly the angle of attack for the best L/D. This is brought out by the chart in Fig. 1.

In speaking of the width of propeller blades as a whole, it has become customary to refer to the ratio of the tip radius to the maximum blade width as the aspect ratio. This aspect ratio has increased in our best propellers for fast turning engines from about 5 to about 7. In considering individual elements of the blade, however, the ratio of the sum of the blade widths to the periphery at the station under consideration is usually taken as a criterion of blade width and is written $B/2\pi R$. This quantity is called the breadth ratio and is analogous to the ratio of developed area to disc area used by naval architects. Fig.

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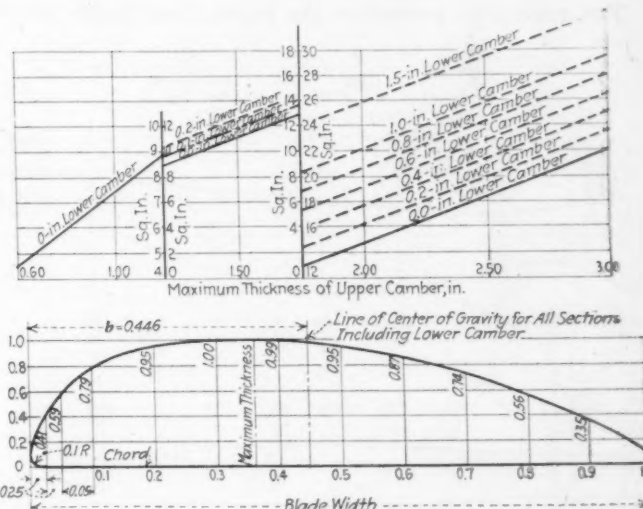
FIG. 2—COORDINATES OF A BRITISH AIRFOIL SECTION ADOPTED FOR USE ON ARMY PROPELLERS

2 shows the coordinates of an airfoil section of British blades has to be varied considerably according to the ser-origin adopted for use on the Army propellers. As the camber ratio is varied at different stations along the propeller blade the section is generated from that shown in Fig. 2 by varying all the ordinates in proportion to the maximum thickness. The plan form of propeller vice of the propeller and the material for which it is designed. The upper portion of Fig. 3 shows a very good plan form, originated by H. C. Watts, of the British Air Board, which is very successful up to tip speeds of
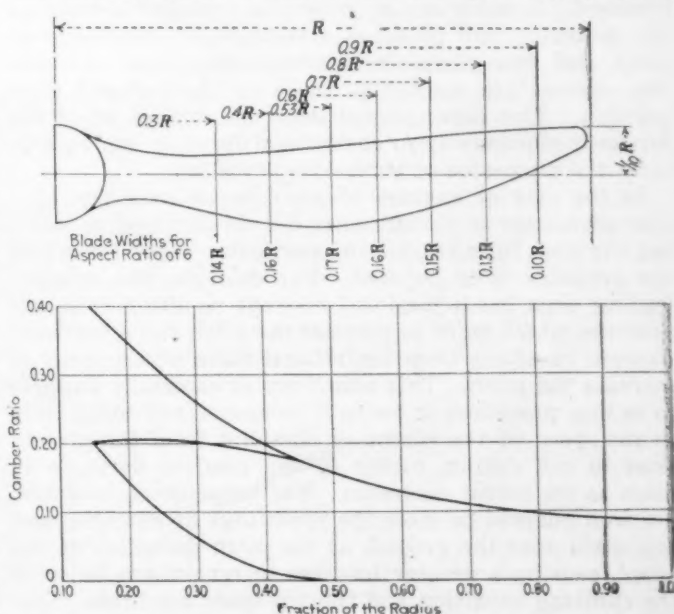
FIG. 3—A PLAN FORM FOR WOODEN PROPELLER BLADES AND UNDERNEATH THE MINIMUM CAMBER RATIO FOR THIS FORM OF PROPELLER AT VARIOUS STATIONS

about 800 ft. per sec. and up to about 400 hp. Up to this speed and power this plan form is very satisfactory for wooden propellers in connection with the thickness ratios shown in the lower part of this illustration. For higher speeds and horsepower a similar plan form may be used, but these thicknesses will have to be increased in most cases. Fig. 4 in the upper section shows a plan form adopted by me for use in Micarta propellers while the lower portion shows a form recommended for steel propellers having an aspect ratio of 9.

For reversible propellers the above plan forms can be
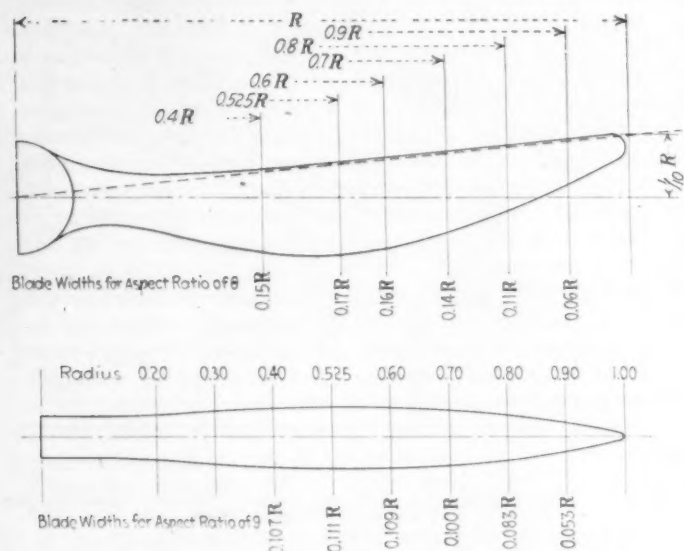
FIG. 4—PLAN FORM (ABOVE) FOR A MICARTA PROPELLER BLADE AND (BELOW) ONE FOR A BLADE MADE FROM STEEL TUBING

used as far as the variations in blade width are concerned, but it is very desirable for reversible propellers to space the centers of gravity for all the sections along a radial line perpendicular to the axis of rotation. If this is done the centrifugal moments are entirely eliminated except insofar as they are produced by the deflection of the blade. This arrangement, however, gives stresses which are symmetrical when the propeller is reversed. In other words, when the propeller is reversed the deflection still produces a centrifugal restoring moment, and since there are no initial centrifugal moments the stresses are similar to those in the forward pitch position. This arrangement does not remove all of the torsional moments from centrifugal force as can be seen from the discussion of reversible propellers.

In the case of engines of small horsepower considerable advantage in performance can be obtained by varying the plan form to suit the particular needs for which the propeller is to be used. For example, the straight leading edge has a torsional moment resulting from air pressure which tends to increase the pitch and a torsional moment resulting from centrifugal force which tends to increase the pitch. This plan form is especially suitable to ceiling propellers as there is comparatively small drop in the speed of the engine in climbing from the ground level to the ceiling, owing to the gradual decrease in pitch as the thrust decreases. The propeller is, however, not well adapted to meet the conditions of climbing and top speed near the ground, as the pitch decreases at top speed, causing a greater increase in revolutions between the climbing condition and the top-speed condition. One plan form is very well suited for climbing and top-speed conditions, but is not very well suited for ceiling. This

plan form and elevation give an arrangement of the center of gravity line which causes the pitch to decrease as the result of the thrust and also as the result of revolutions. As the thrust decreases in going from the climb to top speed the pitch is increased, so that the engine shows a comparatively small gain in revolutions at top speed. The form is not very well suited for ceiling, since the pitch increases as the thrust drops off at ceiling, causing great loss of revolutions near the ceiling. Another plan form which is especially well suited to Micarta propellers as applied to supercharged engines shows a decrease of pitch as the result of the thrust and an increase of pitch as the result of revolutions. As a result, there is a very small gain in revolutions between the top and the climbing speeds. With the ordinary type of engine there is a considerable decrease in revolutions during the climb between the ground and ceiling, but with the supercharged engines there is an increased pitch at high altitude as the result of the drop in the thrust, and also as a result of the increase in revolutions, which is an exceptionally valuable feature. The French have shown considerable skill in the choice of a plan form to accomplish given results by this method which has been successful with small engines. With engines of 400 hp. and over, however, it is not always possible to choose the plan form in view of the performance as there is some difficulty in obtaining a smoothly running propeller free from flutter for these large engines.

Fig. 5 shows a nomogram worked out by Mr. Watts from which the best diameter for given horsepower and engine and plane speeds at ground level can be obtained. This nomogram is very satisfactory for use in connection with the wooden plan form shown in the upper part of Fig. 3, with an aspect ratio of 6 but for this plan form with other aspect ratios and for other plan forms the nomogram is not applicable.

A model test on one of the propellers adopted by Dr. Olmstead showed a maximum efficiency of 88.5 per cent. which is the best result I know of in a practical propeller. Unfortunately, structural considerations have not permitted a very wide application of this type of propeller. It appears probable that this type will be very successful when reduction gearing is applied to very large engines, and it ought to be extraordinarily good for dirigible balloon work.

It is, of course, impossible to go into propeller design very much in detail in a paper of this kind. It may be said, however, that the airfoil theory in connection with the inflow theory has given some very good results and proved to be very valuable for the aerodynamic design of propellers. Both theories have to be applied in the present state of knowledge with a number of empirical factors determined in practice.

PROPELLER THEORIES AND AERODYNAMICS

The basic theory of propellers, at least as far as aircraft propellers are concerned, has been built upon the elemental or strip theory which is due to Drzewiecki. This method of studying the propeller consists of dividing the blades up into zones of given lengths as shown in the upper part of Fig. 6, and assuming that each zone is an airfoil section having certain resultant pressure coefficients at various angles of attack, and a given direction of pressure at each angle of attack. The conception of angle of attack and the direction of resultant pressure are shown in the lower left corner for a given section. In studying propellers by this method, the work absorbed and delivered by each of the sections is

computed and the whole added up to give the total work absorbed and delivered. The efficiency obtained by this method was observed at the start to be far too high and the method was supplemented by the addition of the inflow conception in which the slipstream and race rotation created by the propeller are taken into account.

If v denotes the resultant velocity imparted to the air by an element of a propeller blade and M denotes the mass of air passing through the annulus generated by this element, in a unit of time, then the resultant pressure P on the element is equal to M times v. This is simply the law of impact resulting from fluid passing through the propeller at the disc. It should be borne in mind, however, not only that the resultant pressure P is equal to the product $M\,v$ but that the direction of the resultant pressure P must be opposite to the direction of the resulting velocity v, since action and reaction are equal and opposite. Based on this conception, the mathematicians have gradually evolved the theory that has been worked out in a most complete form by Dr. George de Bothezat.[2]

It would go beyond the scope of this article to go into the derivation of these theories in a very comprehensive manner, but I have tried to give the simplest possible discussion of this theory with the resulting equations. The simplest case of the inflow theory applies to the propeller at fixed point and the diagram for this condition is shown in the lower right corner of Fig. 6. The width of a single blade at a radius R from the axis is denoted by b and the sum of the width of all of the blades is denoted by B. K in the diagram represents the total resultant force on the blade elements and k the resultant pressure coefficient, so that $K = \rho/g\ (kSW^2)$, but the area of the element of all of the blades is $B\partial R$, so that

$$K = \rho/g\ (kB\partial R W^2)$$
$$W = \tfrac{1}{2}v[\cos(\Phi + \beta)\ /\sin\Phi]$$
$$K = \rho/g[kB\partial R(\tfrac{1}{2}v)^2\{\ \cos^2(\Phi + \beta)\ /\sin^2\Phi\ \}] \qquad (1)$$

From the impact theory, however, $K = v\partial M$. Since ∂M is the mass of air flowing through the annulus per unit of time

$$\partial M = \rho/g \cdot \tfrac{1}{2}v \cos(\Phi + \beta)\partial A$$

the inflow velocity being taken as one-half the outflow. $\partial A = 2\pi R \cdot \partial R$; hence

[2] General Theory of Blade Screws by George de Bothezat, National Advisory Committee for Aeronautics Report No. 29, 1918.
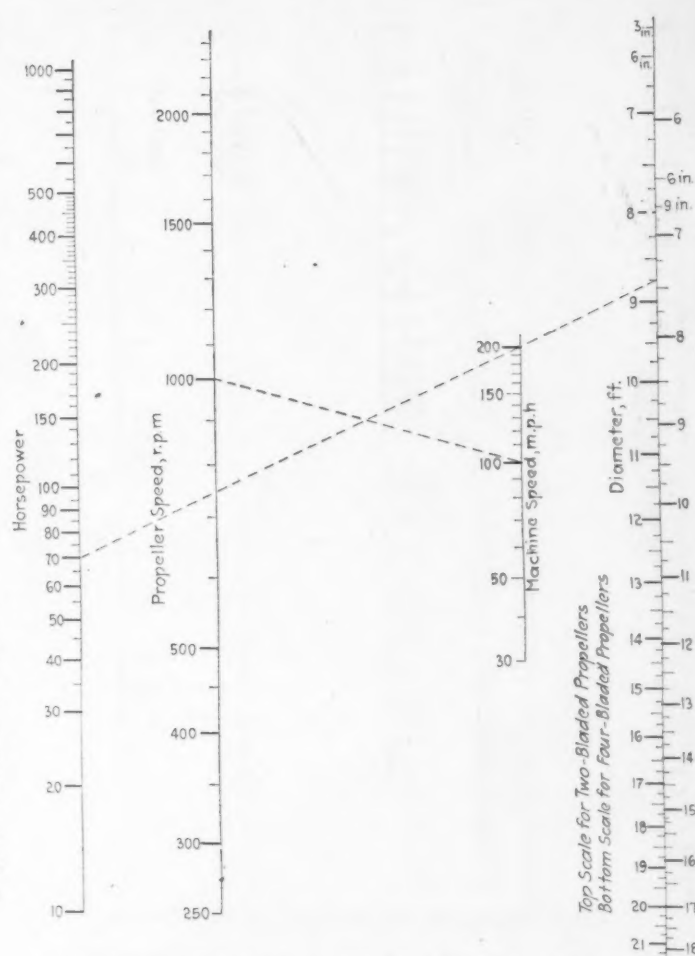
Fig. 5—Nomogram for Determining the Best Propeller Diameter for a Given Combination of Horsepower and Engine and Plane Speeds at the Ground

$$\partial M = \rho/g \cdot \tfrac{1}{2}v \cos(\Phi + \beta) \cdot 2\pi R \cdot \partial R$$

and

$$K = \rho/g[\cos(\Phi + \beta) \cdot 2\pi R\partial R \cdot v]$$
$$= \rho/g(\tfrac{1}{2}v)^2[\cos(\Phi + \beta) \cdot 2\pi R\partial R \qquad (2)$$

Equating (1) and (2) and simplifying we get

$$kB[\cos(\Phi + \beta)\ /\ 2\sin^2\Phi] = 2\pi R$$

or

$$k(B\ /\ 2\pi R) = 2\sin^2\Phi\ /\cos(\Phi + \beta)$$
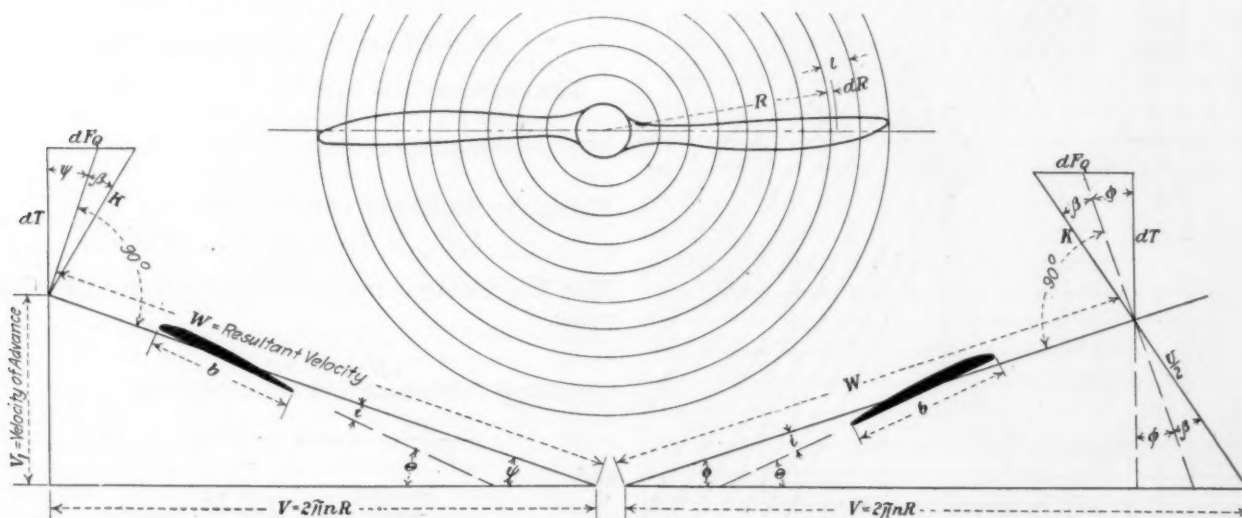
Fig. 6—At the Left the Original Drzwiecki Analysis of the Strip Theory of Propellers Without Inflow, in the Center an Illustration of the Strip Theory of Propellers and at the Right an Analysis of the Velocities and Forces Acting on an Element of the Propeller Blade Rotating at a Fixed Point
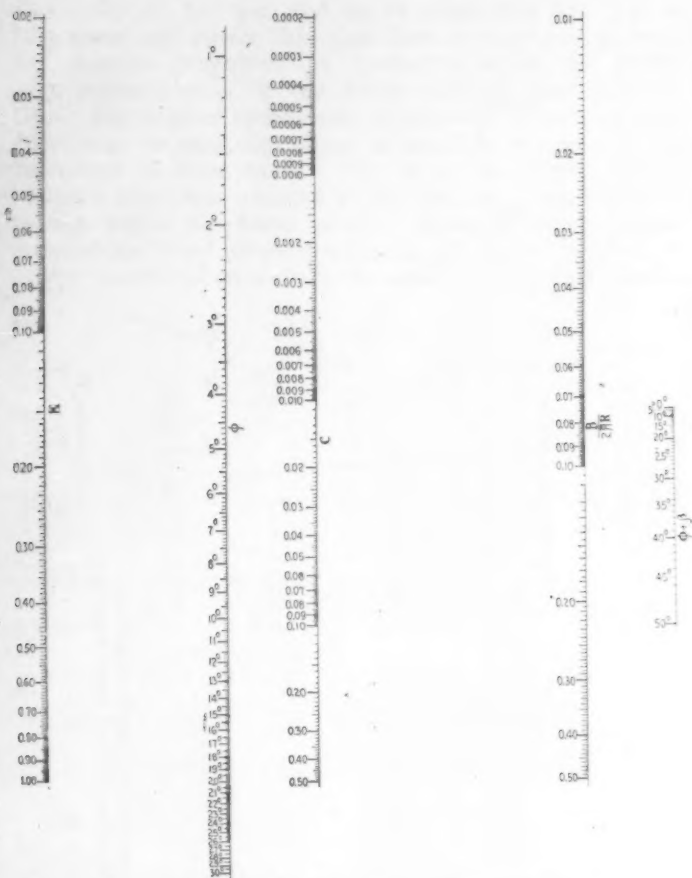
FIG. 7—NOMOGRAM FOR COMPUTING STATIC THRUST
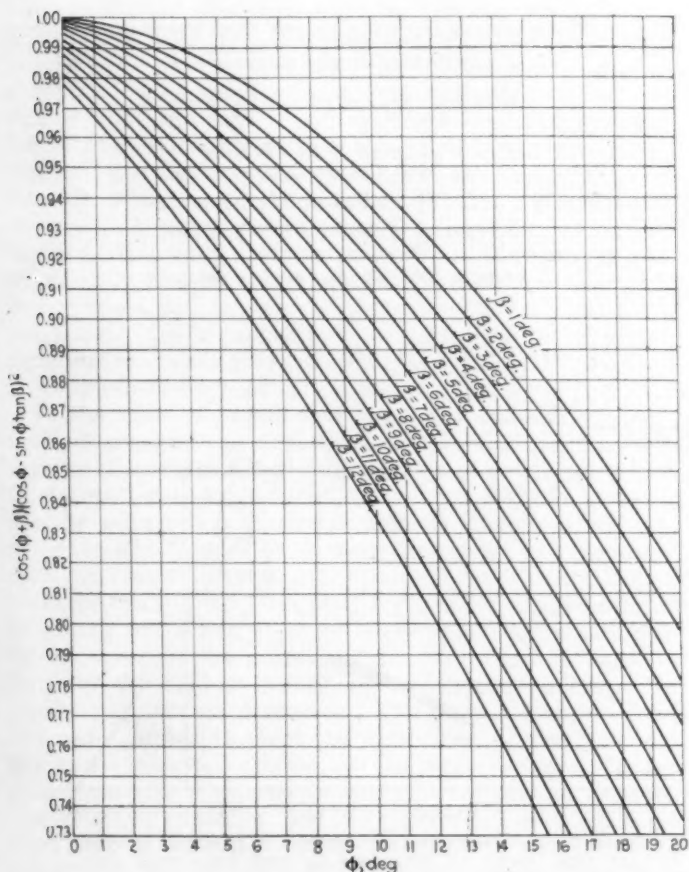
FIG. 8—GRAPHIC CHART FOR DETERMINING STATIC THRUST

This equation permits of a ready solution for ϕ when $B/2\pi R$, k and β are known. The equation is represented graphically by the nomograms in Fig. 7. To find ϕ, connect k and $B/2\pi R$ and find the product on the scale C. Rotate the straight-edge about this point until the value of ϕ, read on the ϕ scale, plus the known value of β, equals $\phi + \beta$, read on the $\phi + \beta$ scale. It can be shown that

$$W = 2\pi nR \ (\cos \Phi - \sin \Phi \tan \beta)$$

so that

$$K = \rho/g \ (K_1 B \partial R) \times (2\pi nR)^2 \times (\cos \Phi - \sin \Phi \tan \beta)^2$$

and since

$$\partial t = K \cos (\Phi + \beta)$$
$$= \rho/g \ (kB) \times (2\pi nR)^2 \times (\cos \Phi - \sin \Phi \tan \beta)^2 \cos (\Phi + \beta) \partial R$$

or

$$\partial T = \rho/g \ [K(B/2\pi R) \times (2\pi)^3 \times N^2 R^2 \times (\cos \Phi - \sin \Phi \tan \beta)^2 \cos (\Phi + \beta) \partial R$$

This can be written

$$\frac{\partial T}{\partial R} = \rho/g \left[\frac{\pi^3}{D_1} \cdot k \cdot \frac{B}{2\pi R} \cdot \left(\frac{R}{R_1} \right)^3 (\cos \Phi - \sin \Phi \tan \beta)^2 \cos (\Phi + \beta) \right] n^2 D_1^4$$

If the quantity in the brackets be plotted against R/R_1 and integrated, we shall evidently find the value of the quantity T_c in the formula

$$T = \rho/g T_c n^2 D_1^4$$

To simplify the calculation for thrust the expression $\cos (\phi + \beta) \ (\cos \phi - \sin \phi \tan \beta)^2$ has been shown graphically in Fig. 8 for various values of ϕ and β.

The torque coefficient Q_c can be computed in a similar way. The value of the ratio of thrust to torque takes a very simple form

$$\frac{\partial T}{\partial Q} - = \frac{1}{R \tan (\Phi + \beta)}$$

In Fig. 1 the ratio of the thrust to the torque force F_q has been worked out for various values of $B/2\pi R$ and various angles of attack for a given airfoil section. It can be seen that the optimum angles for the best value of $\frac{\partial T}{\partial F_q}$ is always lower than the angle of maximum L/D and approaches the angle as a limit as $B/2\pi R$ approaches zero.

At the same time the value $\frac{\partial T}{\partial F_q}$ approaches L/D as limit as $B/2\pi R$ approaches zero.

BEST DIAMETER FOR HIGHEST THRUST

The characteristic equation for thrust is

$$T = \rho/g T_c n^2 D^4$$

The corresponding equation for power is

$$P = \rho/g P_c n^3 D^5$$

Hence the thrust per unit of power is

$$T/P = [\rho/g \ (T_c n^2 D^4) \ ] \div [\rho/g \ (P_c n^3 D^5) \ ]$$
$$= T_c/P_c nD$$

This is evidently a maximum when nD has its minimum value.

$$P = P_c n^3 D^5 = P_c (nD)^3 D^2$$
$$nD = (P/P_c)^{\frac{1}{3}} D - \frac{2}{3}$$

Holding P constant and differentiating

$$\frac{\partial (nD)}{\partial D} = -\frac{2}{3} \left(\frac{P}{P_c} \right)^{\frac{1}{3}} \cdot D - \frac{5}{3} = 0$$

and

$$\frac{\partial^2 (nD)}{(\partial D)^2} = \frac{10}{9} \left(\frac{P}{P_c} \right)^{\frac{1}{3}} \cdot D - \frac{8}{3}$$

Hence the condition for a maximum value of thrust in that the diameter should approach infinity as a limit.

For purposes of lifting, however, the formula for thrust must be modified as the weight of the propeller must be subtracted. In general the selection of proper diameter and speed of revolution will be a question of engineering judgment rather than of calculation, since structural features of the wings, landing gear, etc., must be taken into account. The calculation will serve only to show us what thrust can be realized and what revolutions are required when a maximum diameter has been chosen and the power available is known.

The object in introducing the above discusison is to show that there is no difficulty in obtaining sufficient static thrust for hovering with present aircraft, provided the powerplant and the propeller are modified to suit the conditions. The type of propeller described above would be of entirely too low pitch for level flight, however. To meet both conditions successfully an adjustable-pitch propeller will be necessary. The tests on the Hart adjustable-pitch propeller, whose development has been carried out under my supervision, have shown that we are now in a position to build satisfactory adjustable-pitch propellers without the introduction of any considerable increase of weight.

If this method is extended to apply to forward flight conditions, the formula for ϕ becomes

$$\frac{2 \sin^2 \Phi}{\cos (\Phi + \beta)} = k \cdot \frac{B}{2\pi R} \left[\frac{\tan \Psi}{\tan \Phi - \tan \Psi} + \frac{\tan (\Phi + \beta) \tan \Phi \tan \Psi}{\tan \Phi - \tan \Psi} + 1 \right]$$

Fig. 9 shows a nomogram for the solution of the above quantities to be used in connection with Fig. 10. Thus, knowing k, β, ψ, we can find ϕ and knowing ϕ compute the thrust and torque coefficients as before.

The work absorbed by the element is evidently $\partial F \cdot 2\pi n R$, while the work delivered is $\partial T \cdot V_1$. Hence the efficiency is given by the equation

$$e = \partial T \cdot V_1 / \partial F_Q \cdot 2\pi n R$$
$$= \tan \Psi / \tan (\Phi + \beta)$$

It should be noted that the efficiency found by this method is always lower than the efficiency obtained by the simple Drzwiecki method illustrated in the lower left corner of Fig. 6 where

$$e = \tan \Psi / \tan (\Psi + \beta)$$

MICARTA AND STEEL PROPELLERS

A material which has shown great promise for use in propellers is manufactured by the Westinghouse Electric & Mfg. Co. under the name of Micarta. This material is made up of laminations or sheets of paper or fabric impregnated with Bakelite as a binder. In the case of the propellers the sheets are cut out in a form similar to the laminations of the wooden propellers, laid in a mold conforming to the exact shape of the finished propeller and heated for 3 hr. at a temperature of 350 deg. fahr., and having a pressure of about 1000 lb. per sq. in. The mold is provided with a stripping feature which greatly facilitates removing the finished blades.

Propellers made in this way are finished complete when molded, and are bored for a hub in such a way as to correct any small inequalities in the density of the material which might lead to imperfect balance. The type of hub used is a cylindrical sleeve provided with four keys, a small flange on one end and a nut and loose flange on the other. The density of Micarta is about 1.35, so that the material itself is considerably heavier than wood. The additional weight is usually just about offset by the saving in weight of the hub construction. Two physical
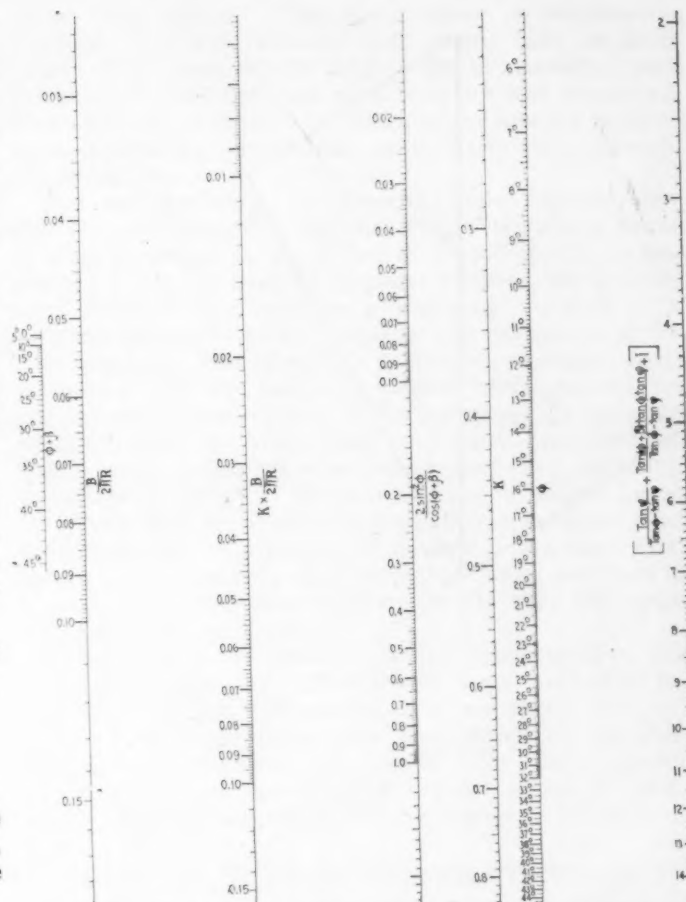
FIG. 9—NOMOGRAM FOR COMPUTING DYNAMIC THRUST

properties of Micarta which make it especially suitable for propeller construction are its great flexibility and the fact that it does not readily take up harmonic vibration. It has the additional advantage over wooden propellers that there is no tendency to split, and the grain can be put in any desired direction. Since the crushing strength is very high it is possible to drive direct by keys, without resorting to the usual construction of flanges and bolts.

Where micarta propellers are used it appears that it will be possible to dispense with the metal hub altogether,
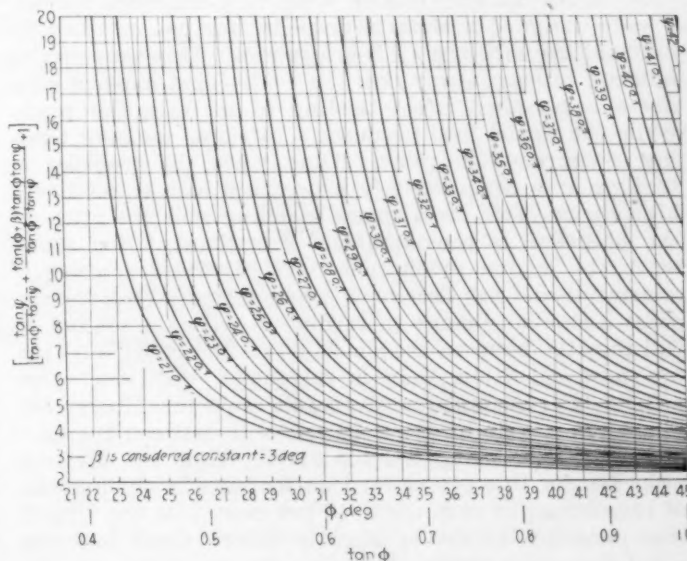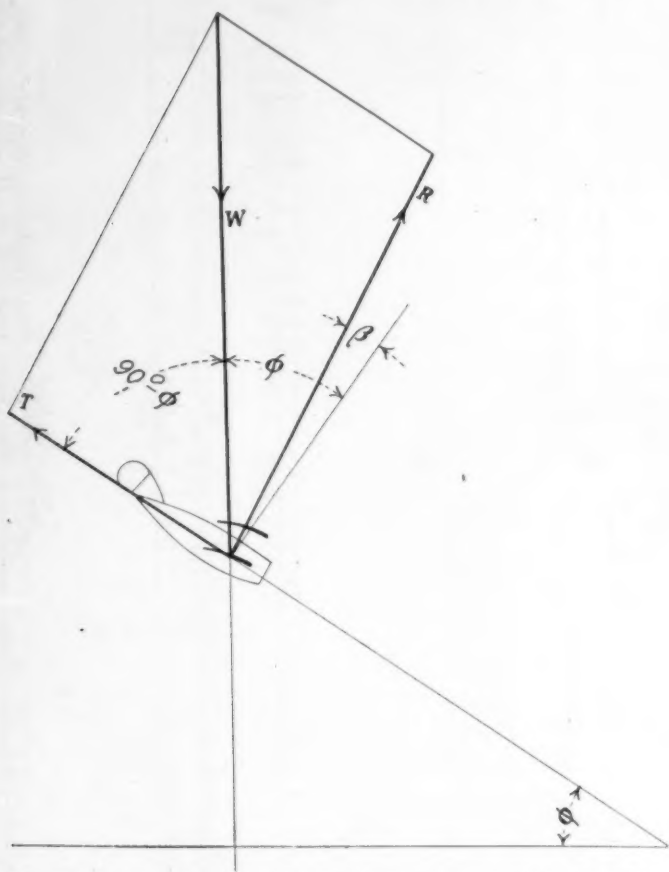
FIG. 10—GRAPHIC CHART FOR COMPUTING DYNAMIC THRUST

FIG. 11—ANALYSIS OF THE FORCES ACTING ON AN AIRPLANE WHEN
GLIDING WITH REVERSE THRUST

provided the single key used at present as in the S.A.E.
Standard shaft-end is replaced by four keys. The ma-
terial is especially well suited to adjustable-pitch and re-
versible propellers, in that it permits of very simple and
light connection between the blade and the hub of the
propeller. It is anticipated that the reversible propeller
with Micarta blades will be considerably lighter and more
durable than the same type propeller with wooden blades,
and will probably be less expensive.

At present a number of Micarta propellers are in ser-
vice on the Liberty engine with very excellent results.
I have designed a Micarta propeller for use on the Lib-
erty engine with the USD-9 airplane. This propeller is
laid out in such a way that the centrifugal moment pro-
duces a torsional effect tending to increase the pitch,
while the thrust load produces a torsional moment tend-
ing to decrease the pitch. Thus, when the propeller is
turning at a comparatively slow speed and at relatively
high thrust, with the airplane standing still, the pitch of
the propeller is considerably lower than at top speed
when the engine revolutions have increased somewhat,
and the thrust has decreased considerably. This feature
gives a smaller change in revolution with the engine at
full throttle, between the condition at fixed point and the
top-speed condition, than is customary with most pro-
pellers. For example, most propellers on the Liberty en-
gine show a gain of about 18 per cent between the con-
dition at fixed point and top speed, while the Micarta
propeller for this job showed an increase in the number
of revolutions of only about 10 per cent. On the USD-9
this propeller showed a slightly better climb and top
speed than the wooden propeller for the same job, al-
though turning about 150 revolutions slower at top speed.

Thus the radius of action on this plane was greatly im-
proved. A propeller of the same design was used by
Major Schroeder in his record-breaking altitude flight.
The feature of the increased pitch with an increased num-
ber of revolutions and a decrease in the thrust is particu-
larly valuable in connection with the supercharger which
was used on this flight, as it gives very simple and direct
automatic control of pitch.

The Micarta propellers are extremely durable, being
very little affected by grass, sand, small stones, rain, etc.
This development appears to have very great possibilities
for improvement of propellers.

An enormous amount of research and experimental
work has been done throughout the world on steel pro-
pellers with little success, as very few, if any, steel pro-
pellers are in actual service at the present time. The
efforts have been concentrated for the most part along
three general lines:

(1) A blade made of two formed sheets welded together
   along the edges
(2) A blade formed from a tube without welding at the
   edges except at the tips
(3) Solid steel blade

Under the first classification an interesting develop-
ment is the Leitner steel propeller designed by H. C.
Watts, formerly of the British Air Board. This type of
propeller is made up of several sheets of thin material
fastened together by riveting, or in some cases by spot
welding. The object of the lamination of the material
is to avoid harmonic vibration by attaching several pieces
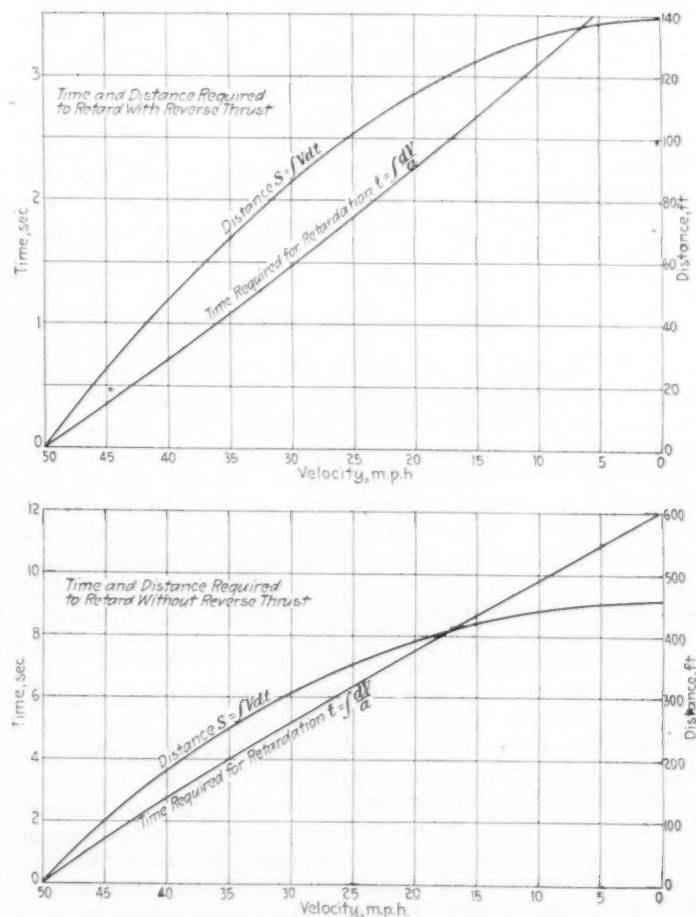having different periods. A number of these propellers

FIG. 12—TIME AND DISTANCE REQUIRED TO RETARD AN AIRPLANE
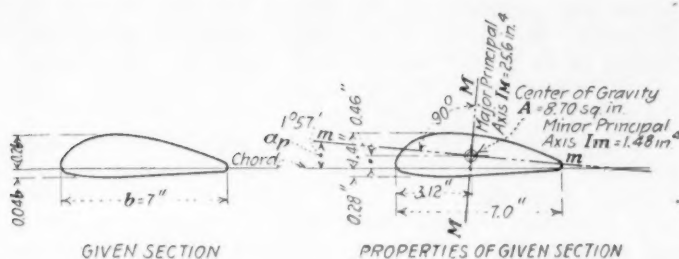WITH AND WITHOUT REVERSE THRUST

FIG. 13—INSTRUCTION SHEET GIVING THE SECTION PROPERTIES FOR STANDARD AIRFOILS FOR PROPELLERS

It is required to find the properties of a standard airfoil section whose blade width is 7 in. with upper and lower camber ratios of 0.20 and 0.04 respectively. The first step is to find the properties of a similar airfoil with a 10-in blade width, and then by the application of the reduction factors obtain the properties for a 7-in. blade width.

REDUCTION TABLE

Item	Symbol	Value for 10-in. Blade Width	Reduction Factor	Value for 7-in. Blade Width
Blade Width, in.	b	10.00	0.7	7.00
Maximum Upper Camber, in.	h_u	2.00	0.7	1.40
Maximum Lower Camber, in.	h_l	0.40	0.7	0.28
Center of Gravity from Left End Measured along Chord, in.	b_c	4.46	0.7	3.12
Center of Gravity above Chord, in.	h_c	0.66	0.7	0.46
Area, sq. in.	A	17.75	$(0.7)^2$	8.70
Angle between Minor Principal Axis and Chord, deg. min.	a_p	1-57	1.0	1-57
Moment of Inertia about Minor Principal Axis, (in.)⁴	I_m	6.17	$(0.7)^4$	1.48
Moment of Inertia about Major Principal Axis, (in.)⁴	I_M	106.30	$(0.7)^4$	25.60
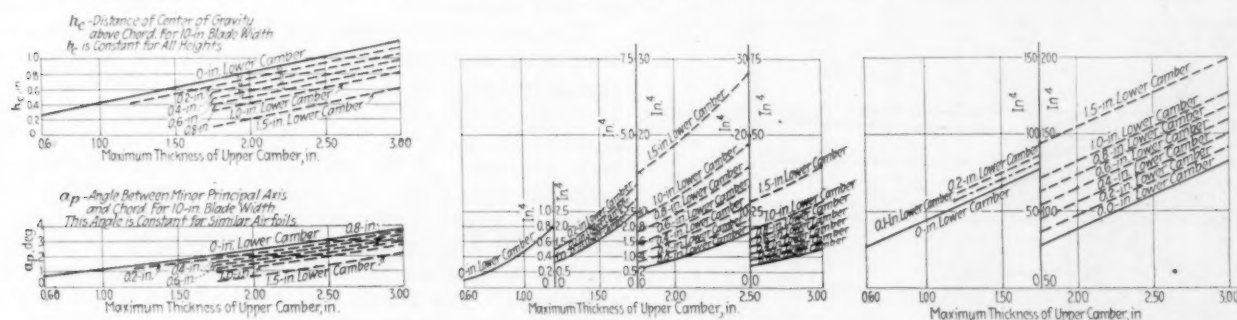
FIG. 14—CHARTS GIVING THE VALUES FOR THE DISTANCE OF THE CENTER OF GRAVITY ABOVE THE CHORD THE ANGLE BETWEEN THE MAJOR PRINCIPAL AXIS AND THE CHORD AND THE MOMENTS OF INERTIA ABOUT THE MINOR AND MAJOR PRINCIPAL AXES FOR A 10-IN. BLADE WIDTH

are said to have been built for small engines and the builders make large claims for its effectiveness.

The most advanced construction of the tubular type is a reversible propeller built by the Standard Steel Propeller Co. of Pittsburgh. On account of the hollow steel construction it is possible to put all the reversing mechanism on the inside of the blade, giving a very clean appearance to the design. In this case the tubing is swaged down and reamed inside and turned outside to give a thickness tapering toward the tip, as well as a diameter tapering toward the tip. After machining, the tubes are brought to a red heat and pressed to shape in a mold. The material used is a nickel uranium steel which shows some very interesting properties for aircraft purposes.

I designed a solid steel propeller to test out the possibilities of the third type of construction. As was anticipated, this showed a terrific flutter at low speeds on account of the extreme flexibility but ran very smoothly

above 1400 r.p.m. The blade stood a remarkable overload test; the cast-steel hub giving way at 2400 r.p.m. The blade, which is 11½ ft. in diameter, was designed for 200 hp., and at this speed was absorbing about 800 hp. This type of construction appears to have some interesting possibilities, particularly with reversible propellers.

The steel-propeller experiments have demonstrated that the most important consideration in the construction of steel propellers is the degree of flexibility. As is explained under the head of propeller stresses, the centrifugal force always provides a restoring moment in a properly designed flexible propeller. In the design of the steel propeller it is necessary to provide sufficient flexibility to obtain this restoring moment without introducing any very great stresses in the material. At the same time, too great flexibility must be avoided; otherwise the result would be too low a period of oscillation, resulting in violent fluttering of the blades. It is my belief, based on a very wide experience in designing and testing steel propellers, that this feature of flexibility is a most vital one in connection with steel propeller design, and that to non-comform with this requirement has been the cause of most of the failures.

In addition to the above-mentioned steel propellers, the Army Air Service has tested a very large number of interesting designs. Moreover, a great many different types of steel propellers have been tested by the Italians, French, Germans and British. The steel propeller experiments have now reached a point where it seems that something very good will be produced in the near future.

ADJUSTABLE-PITCH AND REVERSIBLE PROPELLERS

Considerable attention has been given adjustable-pitch propellers by experimenters in various countries. A
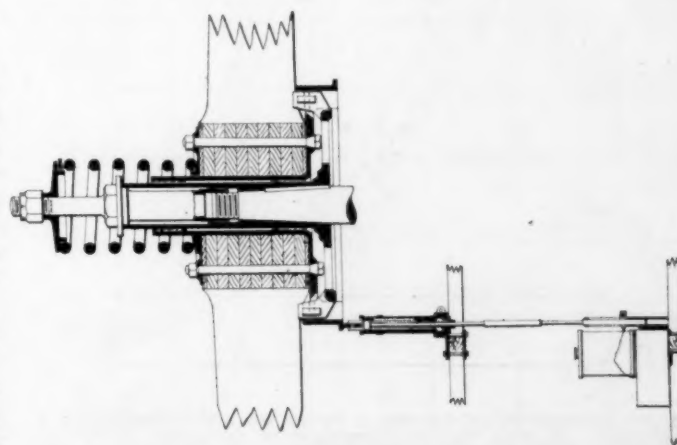

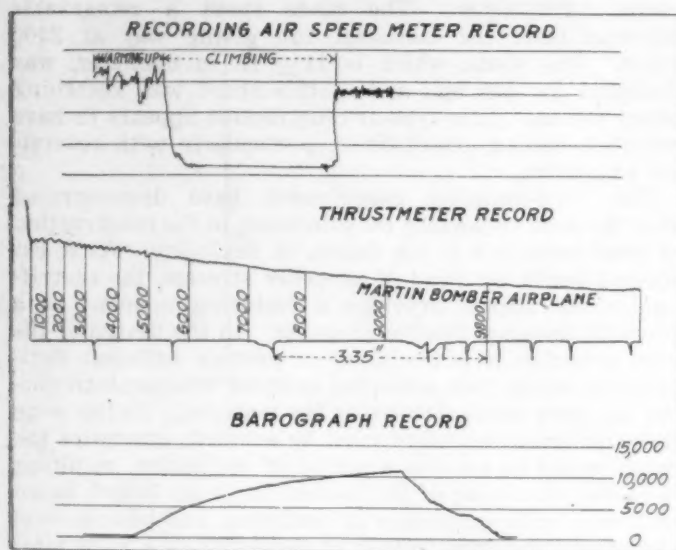FIG. 15—THRUSTMETER FOR MEASURING THE THRUST IN FLIGHT

FIG. 16—RECORDS GIVEN BY AN AIR SPEED METER, THE THRUSTMETER
AND A BAROGRAPH OF AN AIRPLANE FLIGHT

type invented by Professor Reissuer, in Germany, is described briefly in *Technische Berichte*, Vol. III, Section 5. A second type made by Levasseur, in France, has been exhibited at several shows. An adjustable-pitch pro-
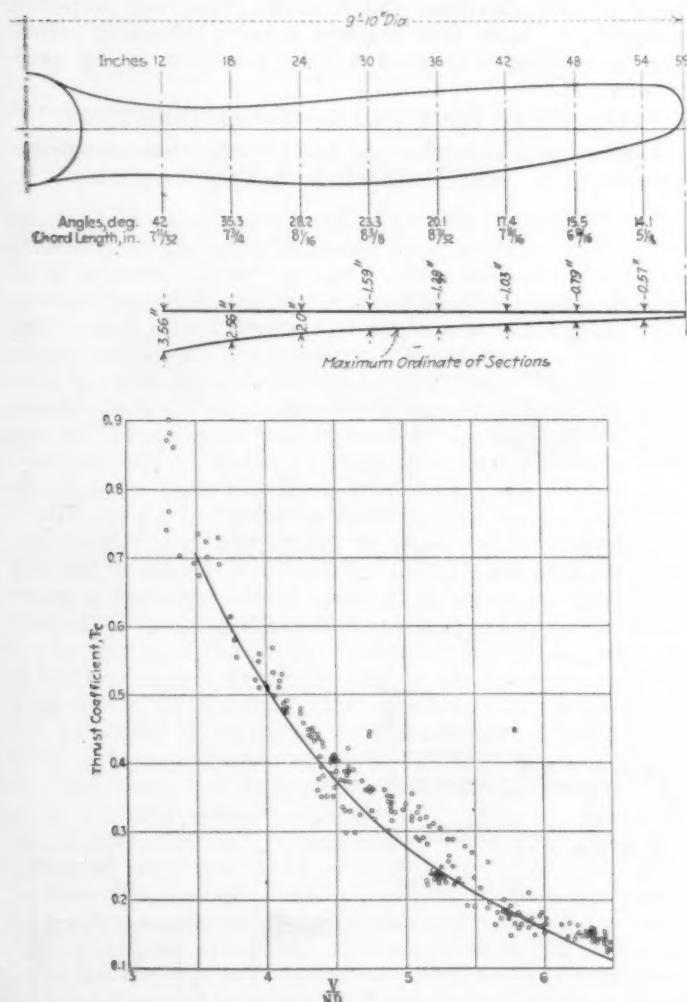

FIG. 17—SECTION ORDINATES FOR A PROPELLER AND UNDERNEATH A COMPARISON OF THE THRUST COEFFICIENTS OBTAINED IN WIND-TUNNEL AND THRUSTMETER TESTS, THE POINTS BEING GIVEN BY THE THRUSTMETER TEST AND THE CURVE BY THE WIND-TUNNEL TEST

peller was produced by the Royal Aircraft Factory in England. So far as I am aware, none of these propellers is in actual service, and from the information available as to their construction it does not appear that the factor of safety would satisfy our requirements.

It is no secret that the Army Air Service has had considerable success with the Hart adjustable-pitch and reversible propellers, but it is impossible for military reasons to make public any details of its construction at the present time. This propeller was invented by Seth Hart of Los Angeles, Cal., and several experimental propellers were built at his expense in California, and a number of flight tests were made there by several pilots. Among the pilots who made the first flights were Earl Dougherty and Lieutenant Mairesse of the French Army. The California flights gave such promise of success that Mr. Hart determined to bring the invention before the Government's Airplane Engineering Department at McCook Field.

The first test given the propeller was a destructive whirling test made to insure its safety for flying purposes. The results of this were so encouraging that the propeller with a few modifications was made ready for flying in a JN-4H airplane. All of the flights with this propeller were made by Caleb Bragg; a very thorough series of tests covering about 8 hr. in the air was made by him. The principal advantages brought out by these tests were that the variable-pitch showed an increase in rate of climb of about 40 per cent as compared with the fixed-pitch propeller, an improvement in ceiling of about 20 per cent and a great gain in the time required for take-off. While it was realized that a considerable length of time would be required to get this propeller ready for production, it was decided to carry on its development as fast as possible without interfering with current production.

The tests have already gone far enough to demonstrate that it is practicable to land an airplane equipped with this propeller on a roof of moderate size and, with some of the modern airplanes, to take-off again. This is possible with existing airplanes designed for military service. With specially designed airplanes the propeller opens the way for a development that should prove of great value to commercial aeronautics. Of course, the first application of adjustable-pitch and reversible propellers ought to be as military and naval equipment. The advantages to the Navy of making possible landings on ships fitted with landing platforms, and to the Army in permitting landings in very small areas, are self evident. Also, the use of the reverse in the air gives the pilot an opportunity for a number of new maneuvers that ought to be very valuable in battle tactics. Reversible propellers in dirigible balloons are well recognized as an aid in maneuvering and in stopping. They are considered essential in ships of very large size. The adjustable-pitch feature of the Hart propellers, which is always combined with the reversible feature, gives a more rapid take-off, a better rate of climb, a higher ceiling, more efficient operation at cruising speed, leading to a greater radius of action, combined with an efficiency at top speed equal to that of the ordinary wooden propeller.

It has been recognized by all those in different countries experimenting with superchargers that the efficient operation of this device is contingent on the development of an adjustable-pitch propeller. This applies with particular force to equipment designed to operate at heights greater than 20,000 ft. The conventional propeller, if designed to operate at 20,000 ft., will turn altogether too

slowly near the ground, and is designed to operate near the ground it will turn altogether too fast at a great altitude. This condition can be met only by the adjustable-pitch propeller, which will permit the engine to operate at a uniform rate at all altitudes. The effect of adjustable pitch on the performance of airplanes with the conventional type of powerplant was described in a paper which I presented before this Society and which was published in THE JOURNAL.[2]

I shall not go into the method of computing performance in detail in this paper. In general, there is a great improvement in the time and distance required for leaving the ground when the adjustable-pitch propeller is substituted for the fixed pitch. At the same time an improvement in the rate of climb, ceiling and cruising radius is possible without any sacrifice of top speed. It may be well to call attention to the method of calculating the distance required to stop a plane equipped with reversible propellers. In this discussion the following notation is employed.

W = the weight of the airplane
V = the speed of the airplane
T = the reverse thrust
t = the number of seconds elapsing after the propeller is reversed
s = the distance covered by the airplane after the propeller is reversed
γ = the value of L/D of the wings corresponding
R = the parasite resistance at unit velocity

The retarding forces are

(1) The reverse thrust or T
(2) The wing drag or W/γ
(3) The parasite resistance or RV^2

The rate of retardation can be computed from the formula $F = Ma$

$$\partial^2 s = (gt/W + g/\gamma + gRV^2/W)\partial t^2$$
$$s = \int_0^t \int_0^t (gt/W + g/\gamma + gRV^2/W)\partial t^2$$

This expression gives the distance which the airplane has traveled during a time t after the reverse is applied.

In determining the effect of reverse thrust on the gliding angle

Φ = the angle of descent (See Fig. 11)
β = the angle between the normal to the path of the airplane and the resultant pressure
    = $\tan^{-1} D/L$
    = $\cot^{-1}\gamma$

Assuming the propeller thrust to be applied parallel to the path

$$W = T \sin \Phi + R (\cos \Phi \cos \beta + \sin \Phi \sin \beta)$$

The following equation connects β, R T and W

$$W = V [T^2 + R^2 - 2RT \cos (90 + \beta)]$$

As an example of the effect of the reverse thrust on the gliding angle, the following can be cited from a practical case. Assume $T = 1000$ lb., $W = 2000$ lb., and $\beta = \tan^{-1} \frac{1}{8} = 7$ deg. 7 min. Then the gliding angle ϕ by the above becomes equal to 36 deg. 50 min. Evidently by varying the reverse thrust any desired gliding angle can be obtained. This feature will, of course, prove valuable in entering a confined space but may require much skill in manipulation.

The forces brought into play in landing are

(1) The parasite resistance of the body
(2) The wing-drag
(3) The friction of the wheels and the tail-skid
(4) The reverse thrust in the case of a reversible propeller

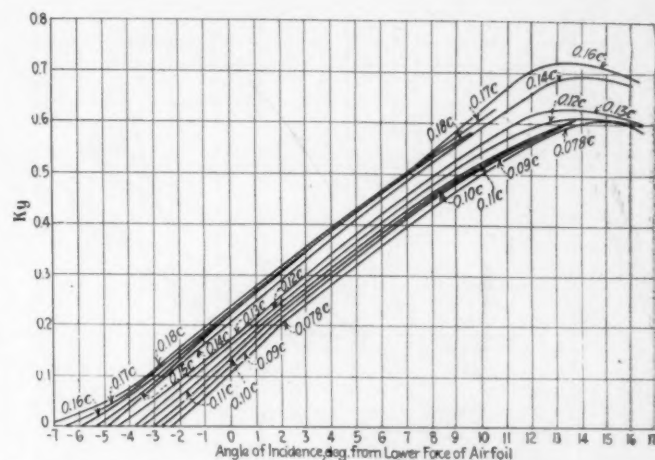[2] See THE JOURNAL, August, 1918, p. 132.

FIG. 18—THE LIFT CHARACTERISTICS OF THE PROPELLER SECTION SHOWN IN FIG. 2

The parasite resistance and wing-drag may be grouped together if we assume the wings to be set at the stalling angle. In this case resistance, parasite and wing drag will be proportional to the square of the speed. The sum of the two can then be written RV^2.

The coefficient of friction on the wheels can be taken as f and the load on the wheels will be the weight minus the lift, or $(W - K_y AV^2)$ where K_y is the maximum value. The frictional resistance will be $f (W - K_y AV^2)$.

The total retarding force in the case of an airplane without reverse thrust will be

$$RV^2 + f (W - K_y AV^2) = W/g \times \text{the retardation}$$

The formula for the distance required to stop without reverse thrust is

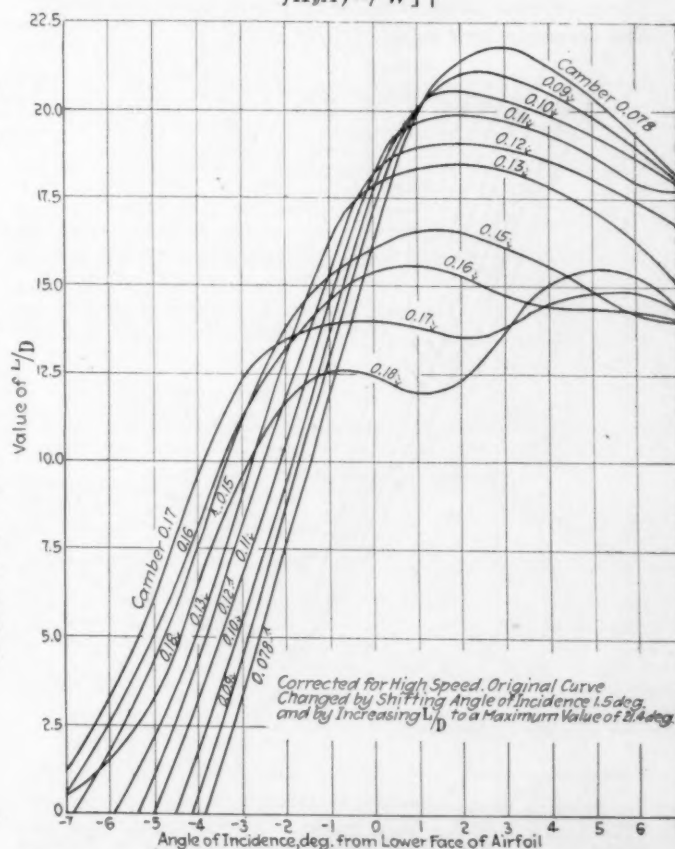$$s + c_i = - [W/g (R - fK_yA)] \log \{ \sec [(t + c_1) g (R - fK_yA)^{3/2} / W] \}$$

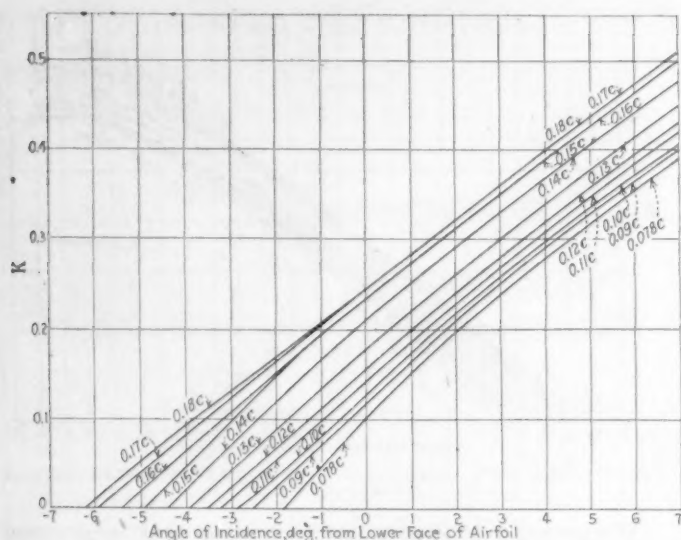FIG. 19—THE L/D CHARACTERISTICS OF THE PROPELLER SECTION SHOWN IN FIG. 2

Fig. 20—Curves Giving the Total Resistance Coefficient for the Propeller Section Shown in Fig. 2

In case reverse thrust is applied, the expression for the distance traveled becomes

$$s = g/W \int_o^t \int_o^t [RV^2 + f(W - K_y AV^2) + T]\partial t$$

Since the thrust is variable and cannot be expressed readily in terms of v or t, it is necessary to resort to a graphical method.

The following data can be assumed to constitute an example of landing conditions:

Weight of airplane complete = 2075 lb.

Area of supporting surface = 250.5 sq. ft.

The parasite resistance is equal to 0.01127 V^2

The maximum value of K_y in lb. m.p.h. units = 0.00265

The corresponding value of L/D is 7.5
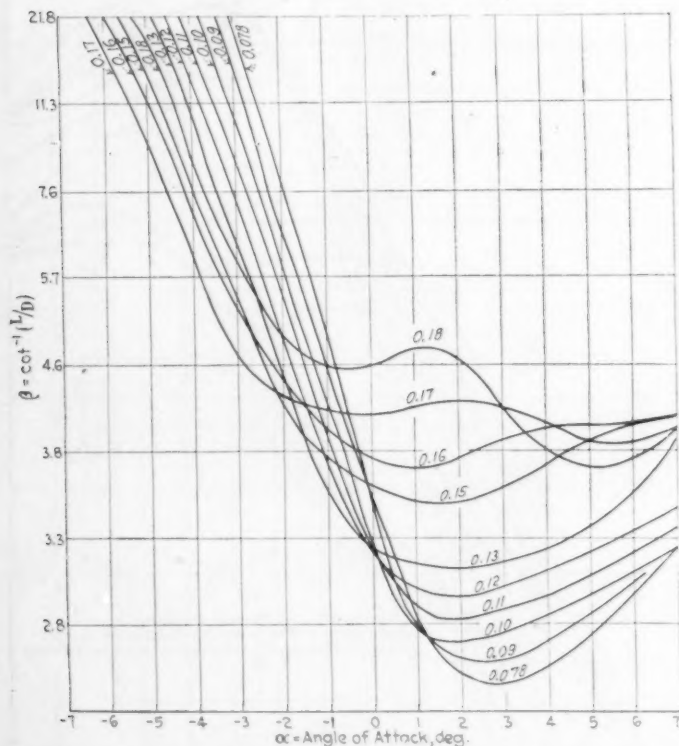
Fig. 21—Angle between the Normal to the Path and the Direction of the Resultant Pressure for Airfoils of Various Thicknesses

The coefficient of friction between the wheels and tail-skid and the earth is 0.2

The corresponding time and distance required to stop are shown in the two sections of Fig. 12.

PROPELLER STRESSES

The question of propeller stresses has received considerable attention during the last few years and the following are well recognized and computed:

(1) The direct tension due to centrifugal force

(2) The bending moments in the thrust and torque plane due to centrifugal force

(3) The bending moments in the thrust and torque plane due to air pressure

In addition to the above, however, very important stresses are introduced by the torsion due to the air pressure and by the torsion due to the centrifugal force.
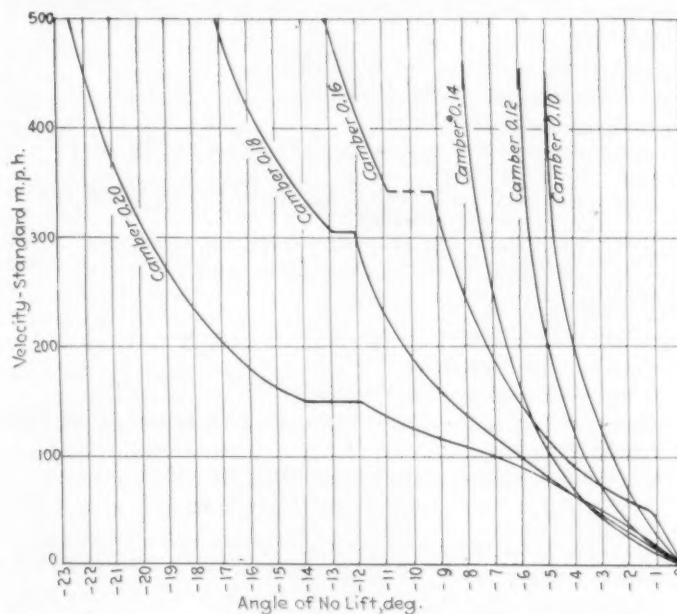
Fig. 22—Curves Showing the Change in the Angle of Zero Lift as the Speed Increases

In computing stresses it is convenient to start out with the centrifugal force at various stations along the blade. This centrifugal force is computed from the cross-sectional area at the radius of the element under consideration. Applying this formula, the centrifugal force is equal to 1.227 $\Delta A L N^2 R$, the value of Δ being taken as the density of the material. From these values the centrifugal force acting on each section can be found and, knowing the relative location of the various sections, the bending moments due to centrifugal force can be computed. The thrust and torque are computed from the characteristics of the airfoil sections and the resulting bending moments found.

If the section properties of the various cross-sections of the propeller are known, the stresses can be computed by the usual method of analytical mechanics. The section properties for the series of airfoils referred to in this paper are tabulated in convenient form in Figs. 2, 13 and 14, and can be worked out very rapidly for a propeller section of given camber ratio and width from Fig. 13 by following the instructions given underneath the illustration. For most purposes these section properties will apply to airfoils of somewhat different shape with sufficient precision, provided the camber ratio is known.

In making a static stress analysis of a propeller it should be borne in mind that no action of the deflection of the blade is taken into account. This deflection nearly always results in a considerable reduction of the stress on account of the restoring moments introduced by the centrifugal force. The static stress analysis gives a fairly good comparison of strength values of propellers, provided the shape of the blade is such that it is free from flutter.

PROPELLER TESTING

Propeller tests are usually carried out in four ways; (a) flight tests to determine the efficiency and adaptability of the propeller, (b) wind-tunnel tests to determine the efficiency and adaptability of the propeller by tests on a small model, (c) whirling tests to determine the factor of safety and structural features of full-size propellers and (d) tests made on propeller materials and processes of manufacture. Flight tests of propellers have been rather difficult owing to the many sources of error which may reduce the precision and to the lack of suitable instruments. At the present time, however, there are a number of instruments available and under devel-
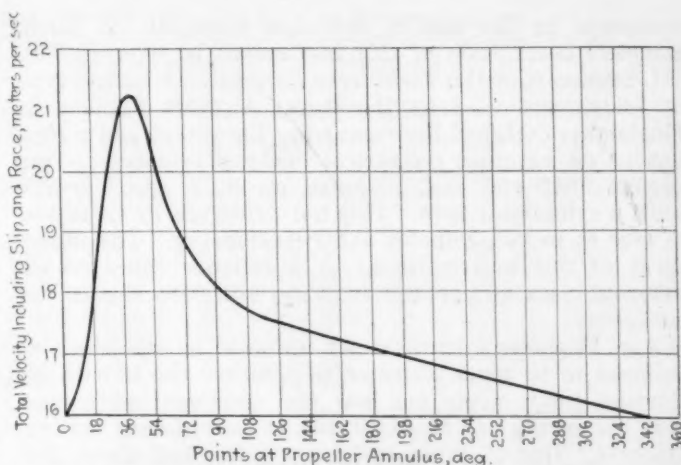
FIG. 24—DISTRIBUTION OF THE PRESSURE AND VELOCITY AROUND THE PROPELLER ANNULUS AT A RADIUS OF 30 CM. (11.81 IN.)

sary to carry these tubes all the way around the propeller and the construction is rather clumsy in this respect. It appears that the construction has also been
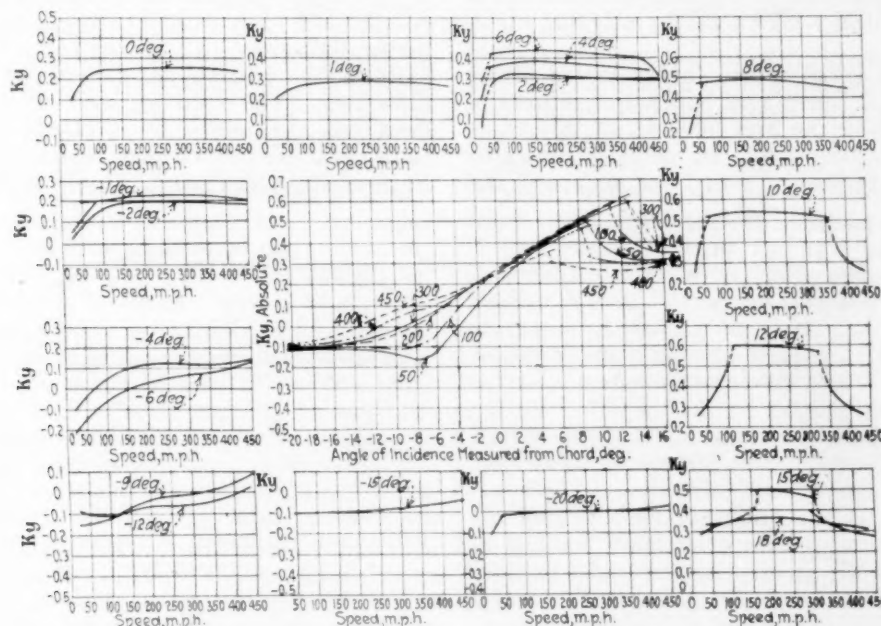
FIG. 23—CURVES SHOWING A DECREASE IN THE LIFT COEFFICIENT AND A SIMULTANEOUS INCREASE IN THE DRAG COEFFICIENT WHERE THE TYPE OF AIR-FLOW CHANGES

opment which ought to make these tests more satisfactory. In addition to the altimeter, barograph, chronometric tachometer, recording and indicating air-speed meters and thermometers which are used in airplane testing, it is desirable to have thrust and torque meters and a satisfactory means for measuring the slip and race velocities when testing propellers. I shall attempt to give a very brief description of some of these special instruments which have been developed in the last few years.

An instrument which has the very desirable feature of giving simultaneous readings of thrust and torque is the dynamometer hub developed by Dr. Bendemann and tested by the Germans on a Rumpler C-2. The thrust and torque reactions are taken up by pistons working in cylinders filled with oil and the resulting oil pressure is recorded on a drum located in the cockpit. This pressure is led from the cylinders to an extension of the crankshaft and thence through oil-tight grooved rings to a series of tubes leading to the cockpit. It is neces-
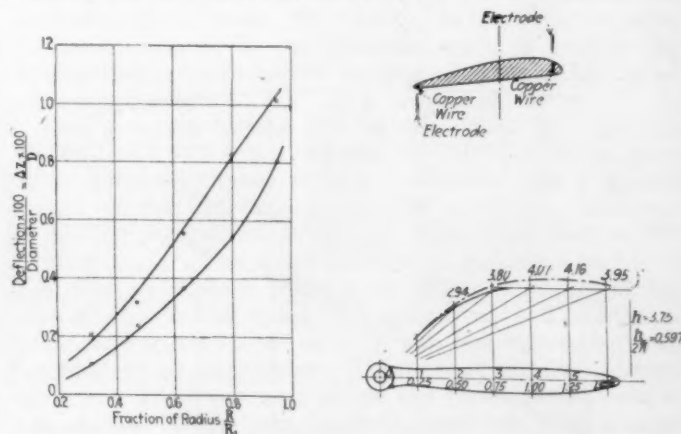

FIG. 25—AT THE LEFT DEFLECTIONS OBTAINED IN A WHIRLING TEST ON A GERMAN PROPELLER AND IN THE UPPER RIGHT CORNER THE METHOD OF MEASURING THE DEFLECTIONS BY ELECTRIC CONTACTS WITH THE CHANGE OF PROPELLER PITCH RESULTING FROM THESE TESTS UNDERNEATH

hampered by the lack of first-class material. A fairly complete description of this instrument is given in Vol. III, Section 6, of the *Technische Berichte*. A second type of instrument used by the Royal Aircraft Factory in England is designed for measuring the thrust and makes use of an external cylindrical bushing attached to the engine shaft-end and, mounted on it, a propeller-hub with a cylindrical bore. This hub is driven by links and is free to move against a calibrated spring. The movement of this hub is traced by a follower roller on an external track and is read from an indicating dial in the cockpit.

Fig. 15 shows a thrustmeter designed by me which is believed to be much sturdier than either the British or German instruments and has the additional advantage that the spring can be calibrated on an ordinary testing machine. One of these instruments has had about 100 hr. in the air, including a flight from Dayton to Washington and return, without any serious wear. There is no appreciable vibration and the pilots do not even remove the instrument when the ship is wanted for cross-country flying. The recording drum in this case is mounted directly on the nose of the engine to avoid any errors introduced by the weaving of the airplane structure.

It is interesting to compare the thrust record shown in Fig. 16 with the air-speed and barograph records of the same flight. During the first 5000 ft. of this climb the air was bumpy or full of whirls. This is shown by the wavy lines in the records of thrust and air speed, and

to a somewhat less degree in the barograph record. Above 5000 ft. smoother air was encountered and all three records show a smooth continuous line.

A comparison of the results obtained in the wind-tunnel with the full-scale results obtained from this instrument is interesting. The principal dimensions of the propeller design on which the tests were run are given in the upper part of Fig. 17. The full-scale propeller was 9 ft. 8 in. in diameter, and the wind-tunnel model was 3 ft. in diameter. The wind-tunnel tests were run at Leland Stanford University. A comparison of the thrust coefficients is shown in the lower portion of Fig. 17. The errors in the full-scale thrust coefficient are not thought to be due to lack of precision but rather to the difficulty of synchronizing the readings of the air-speed meter, tachometer, barograph, thermometers and thrust-meter. This emphasizes the desirability of recording all of these readings on the same chart. At the present time three different types of torque meter are being developed for airplane use, and it is anticipated that some very valuable propeller and engine data will be obtained when these are available.

The wind-tunnel tests, being less expensive, have been carried out on a rather comprehensive scale under two main divisions; (a) experiments with wing sections suitable for airscrew design and (b) tests of models for airscrews. The most valuable work under the former head has been done in England, while comprehensive tests of model screws have been carried out in England, France, Italy, Germany, Russia and the United States.
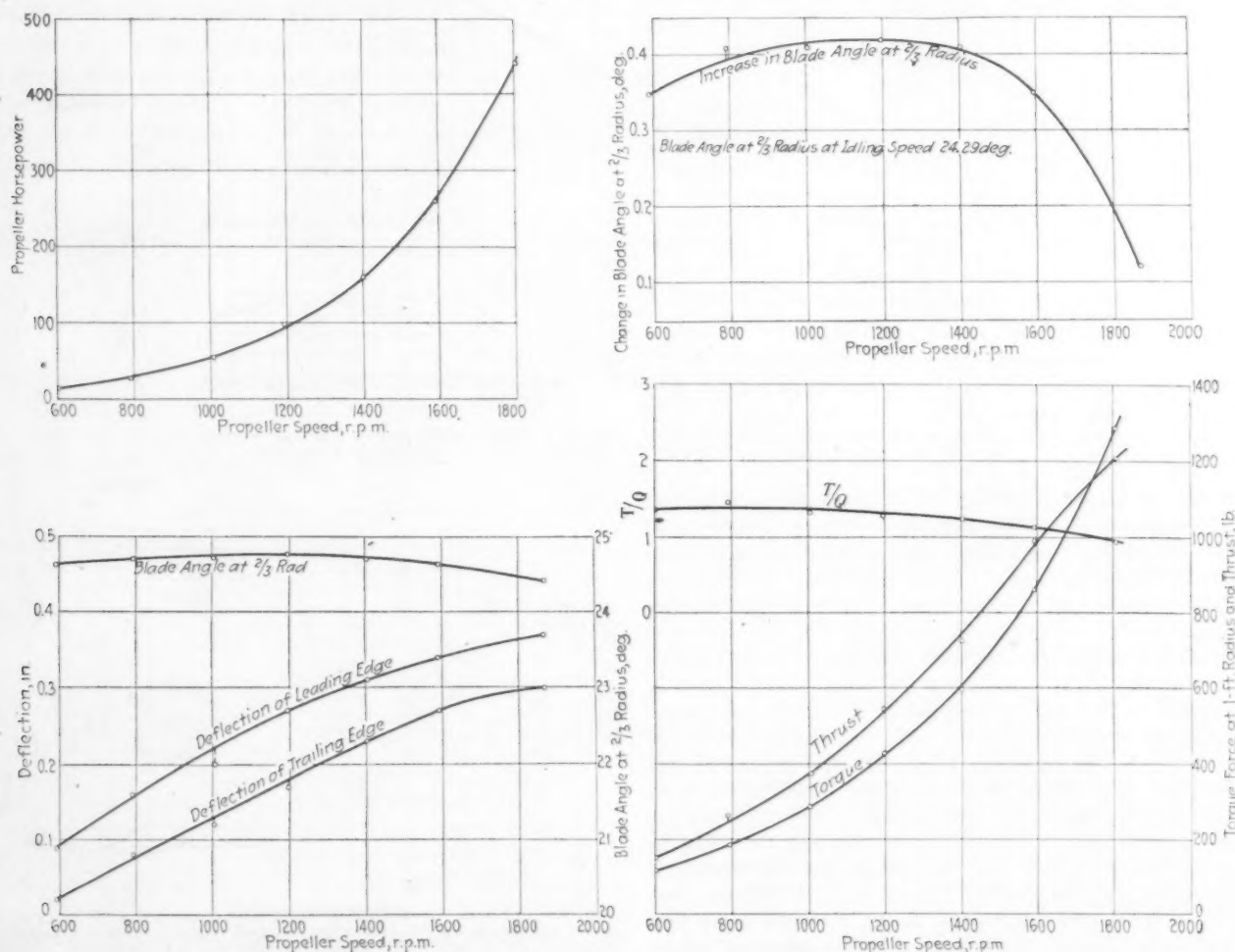

FIG. 26—A TYPICAL SET OF READINGS FROM A PROPELLER TEST MADE AT McCOOK FIELD

TABLE 1—ACTUAL AND COMPARATIVE PROPERTIES OF VARIOUS WOODS AND OTHER AIRPLANE PROPELLER MATERIALS

Common and Botanical Name	Specific Gravity at 15 per cent Moisture Including Water	Shrinkage from Green to Oven-Dry Condition		Strength in Bending — Modulus of Rupture, per cent	Strength in Compres'n Parallel to Grain — Maximum Crushing Strength, lb. per sq. in.	Strength in Compres'n Perpend'r to Grain — Fiber Stress Elastic Limit, lb. per sq. in.	Stiffness — Modulus of Elasticity in Bending, lb. per sq. in.	Hardness — Load Required to Imbed a 0.44-in. Ball for One-Half its Diameter, lb. per sq. in.	Shock Resisting Ability, lb.	Shearing Strength Parallel to Grain, lb per sq in.
		Radial, per cent	Tangential, per cent							
Birch, yellow (Betula lutes)	0.63	6.9	8.9	13,200	7,040	803	1,800,000	980	19.0	1,622
Cherry, black (Prunus serotina)	0.54	3.7	7.1	12,030	7,080	777	1,632,000	883	12.8	1,990
Spruce, Sitka (Picea sitchensis)	0.39	4.5	7.4	8,240	5,200	570	1,480,000	490	6.4	1,165
Maple, Oregon (Acer Macrophyllum)	0.51	3.7	7.1	11,080	6,480	970	1,370,000	830	8.7	1,660
Oak, white (Quercus alba)	0.68	6.2	8.3	12,120	7,000	1,450	1,420,000	1,310	12.1	1,790
Walnut, black (Juglans nigra)	0.59	5.2	7.1	14,230	8,600	1,051	1,770,000	1,195	14.6	1,822
Poplar, yellow (Liriodendron tulipifera)	0.42	4.1	6.9	8,350	5,100	542	1,570,000	450	5.6	1,180
Micarta	1.35	...	...	20,000	30,000	....	500,000	.....	....	2,000
Mild Carbon Steel (Soft)	7.84	...	...	60,000	......	....	29,000,000	.....	....	.....
Alloy Steel (Heat-Treated)	7.84	...	...	100,000	......	....	30,000,000	.....	....	.....

It is impossible to do more than touch on this field of experiment in an article of this kind. A series of sections of British origin, which I have used to some extent with very good results, was shown in Fig. 2. The lift and L/D characteristics of these sections are shown in Figs. 18 and 19. The lift coefficients are the uncorrected values obtained at 30 m.p.h., while the L/D values are corrected for high speed. The same data are shown in Figs. 20 and 21, except that the total resistance coefficient is shown in one curve and the angle whose tangent is D/L is shown in the other. This is more convenient for studies of the inflow theory as the mathematics is considerably simplified in this way. I have recently completed some experiments, in conjunction with E. N. Fales, in the high-speed wind-tunnel which we have developed at McCook Field. It has been possible to carry these experiments up to a true air speed of 500 m.p.h. on account of the exceptionally uniform traverse of the air-flow in this tunnel and some new features of propeller airfoils have been brought to light. Of particular interest is the change of the angle of zero lift as the speed of the air increases. In Fig. 22 it will be seen that the angle of the chord at zero lift changes very slightly for thin airfoils, such as used in airplane wings, while the change in thick sections, such as are sometimes used in propellers, is enormous. Of further interest has been the visualization of the air-flow, of which numerous photographs have been obtained. In all of the airfoils tested we encountered at high speeds a critical velocity where the type of air-flow changes, the lift coefficient showing a sudden decrease and the drag coefficient a simultaneous increase as illustrated in Fig. 23. It is interesting to see the change in the air-flow at this critical speed as the flow changes in the same way for all the models.

One cannot give too much praise to the extremely careful and conscientious airfoil work done at the National Physical Laboratory in England. This work has formed the ground-work for much of the experimental work in propellers. Many valuable airfoil data have also been furnished by Eiffel, Costanzi, Prandtl and numerous other experimenters. Dr. Durand's monumental series of propeller tests is now so well known as to need no description. In addition to the published tests, many models of Air Service propellers have been tested at the Leland Stanford University through the cooperation of Dr. Durand and Professor Leslie. Of special interest among recent-model propeller tests is the series of tests of Eiffel with tandem propellers. M. Eiffel has shown that it is possible to have a tandem arrangement with very high-pitch propellers rotating in opposite directions, where the combination shows a higher efficiency than either propeller running alone owing to the absence of race rotation in a properly designed tandem combination. M. Drzwiecki has published the results of an extraordinarily interesting series of experiments wherein he obtained the instantaneous velocity distribution throughout an annulus of the propeller disc, and has shown the presence of a circulation about the propeller blade analogous to that known to exist about airplane wings. It appears that this series of experiments will make necessary a modification of the inflow theory which has become fairly well established during the last few years. (See Fig. 24.)

The facilities for making whirling tests of practical propeller designs, construction and materials have been fairly well developed in England, Germany and the United States; but, as far as I know, the French and Italians still depend on static tests. I am told that the French Section Technique was unable to obtain facilities of this kind during the war, owing to the scarcity of electrical machinery in France. The European whirling stands are all comparatively small; the largest so far as I know being capable of developing about 600 hp. The British have about three of these stands and make a very large number of tests. The Germans have a whirling stand for testing. In testing they have studied deflections in much the same way as we have studied them at McCook Field, taking the deflection of the leading and trailing edges and computing the change in angle. The upper view in Fig. 25 shows the test described by H. Dietzius in Vol. III, Section 2 of the *Technische Berichte*. The deflection measurements are obtained by means of electric contacts, but the exact method is not clearly described in this article. The results are typically the same as those observed in our propeller work, a greater deflection being noted on the leading edge, resulting in an increase of pitch.

The propeller-testing laboratory of the Air Service at McCook Field has a capacity of 1400 hp. for a short time, and is equipped with a bombproof and a special device, so that the propeller can be completely destroyed in testing without throwing any unbalanced load on the driving-shaft. The usual practice in making a test on a propeller at McCook Field is to obtain readings of the torque, thrust and speed, the deflections and change of pitch, at various speeds up to 50 per cent above the rated horsepower of the engine. This test is usually followed by a run at 50 per cent above the rated horsepower of the engine. It has been found that this test gives a satisfactory factor of safety for wooden propellers. For propellers of other materials, special tests are carried out according to requirements of the material. The readings

of thrust are obtained directly from the Toledo scale, and the readings of torque are taken both electrically and mechanically. The deflections are read by a telescope with cross-hairs which is adjusted until it lies in the plane of revolution of the leading and trailing edges respectively. A typical set of readings from one of these propeller tests is shown in Fig. 26.

A water-spray test also is arranged, and tests of the resistance to abrasion are run from time to time. One of the most complete tests carried through consisted of a 200-hr. run on a Micarta propeller designed for the Liberty Engine.

Tests of propeller material are of considerable impor-

tance, the quality of wood being usually determined by the specific gravity rather than by a strength test, owing to the great variation in results of strength tests, according to the method by which they are made, and depending upon the manner in which they are carried out. The specific-gravity test is very positive and appears to give a very clear indication of the quality of material. The most elaborate series of tests of wood with which the writer is familiar is that made by Mr. Newlin, of the Forest Products Laboratory. I have compiled some of the properties of a number of propeller woods, together with those of annealed steel and Micarta; these are given in Table 1.

HEAVY TRAFFIC PAVEMENTS

THE load-carrying capacity of any type or design of pavement must of necessity be influenced by the support afforded the pavement from below. Such support is furnished by that portion of the earth directly below the pavement, known as the subgrade. The supporting value of natural subgrades varies enormously, as illustrated by the two extremes of muck or quicksand and solid rock. Most subgrades consist of soil lying between the extremes mentioned but still varying greatly in their supporting value depending not only upon the type but upon the moisture content and the degree of compaction. With very few exceptions any well-compacted soil will of itself support the heaviest conceivable traffic if its moisture content is properly controlled and if it is protected by a structure which prevents the displacement of particles at its surface. The protective structure termed the pavement will then need to be only of sufficient thickness to afford such protection and at the same time itself withstand the various destructive agencies of traffic. For a given traffic this thickness will depend largely upon the type of pavement.

The bearing capacity of most soils, particularly the clayey types, decreases as their moisture content increases above a certain point. Although there is much yet to be learned regarding the comparative bearing value of soils this fact is generally recognized and various drainage methods are employed to control the moisture content of the subgrade. Proper drainage is the first essential for maintaining a dry subgrade and measures taken to prevent the access of water to the subgrade directly below the pavement are often more important than measures designed to remove the accumulations of water in the subgrade. Some soils are so persistently retentive of moisture once absorbed that it is impossible to remove it with sufficient rapidity by any ordinary system of drains. Certain clayey soils belong to this class and when all practical preventive measures in the way of drainage are likely to prove inadequate it may well be advisable to modify the character of the subgrade material. Thus

at relatively low cost a clay subgrade can often be greatly improved by mixing it with sand in exactly the same manner as in the construction of a sandy-clay road. Such a mixture will not only retain less moisture than the clay but will possess a much higher supporting value than moist clay.

Any rational design of highway should take into account the fact that the subgrade must ultimately take the weight and shock of traffic as transmitted through the pavement and practically any reasonably dry subgrade will do this if it is compacted and its surface is protected from displacement. Careful attention to subgrade preparation and drainage is, therefore, the first essential to be considered.

The asphaltic concrete pavement is highly resistant to impact which is recognized as the most destructive traffic factor and under impact develops as a single unit relatively high slab and beam strength.

It is manifestly uneconomical, if not impracticable, to adopt a design of highway which will permanently bridge appreciable areas of weak subgrade. While the asphalt type develops bridging action to an appreciable extent it will of itself constantly seek to maintain contact with the subgrade at all points and thus reinforce itself with the maximum supporting value of the subgrade. The rigid type of pavement or base cannot do this because of its inherent characteristics. It is, therefore, almost sure to crack eventually where appreciable areas of subgrade fail to support it uniformly.

Both the service history of asphalt-base pavements and test data indicate that under given conditions it is not necessary to adopt as massive a design for the flexible type of base as for the rigid type. It is difficult for engineers who have had no opportunity to observe the asphalt-base pavement under heavy traffic to think of it in terms of less thickness than the rigid base but in the light of present experience such consideration appears to be entirely warranted.—From a paper presented before Engineers Club of Philadelphia, by Prevost Hubbard, chemical engineer, Asphalt Association.

COMPARISON OF ORDINARY WOOD WITH PLYWOOD

THE properties of wood in various directions relative to the grain differ widely and this variation must be recognized in all wood construction according to Technical Note No. 131 of the Forest Products Laboratory, Madison, Wis., and the difference in properties along and across the grain must be utilized to the best advantage by employing the proper size and form of parts. The tensile strength of wood parallel to the grain may be 20 times as great according to tests made at the laboratory as perpendicular to it and its modulus of elasticity is from 15 to 20 times as high. The shearing strength perpendicular to the grain is, however, much greater than parallel. The low parallel-to-the-grain shearing strength makes the utilization of the tensile strength of wood along the grain difficult, since failure will usually occur through shear at the fastening before the maximum

tensile strength of the member is reached. The large shrinkage of wood across the grain with a changing moisture content may introduce distortions in a board that decreases its uses where a broad, flat surface is desired. The shrinkage from the green to the oven-dry condition across the grain for a flat-sawed board is about 8 per cent and for a quarter-sawed board about 4½ per cent, while the shrinkage parallel to the grain is practically negligible for most species.

It is not always possible to proportion a solid plank so as to develop the necessary strength in every direction and at the same time utilize the full strength of the wood in all directions of the grain. In such cases plywood meets this deficiency by cross banding which results in a redistribution of the material. In building up plywood an effort is made to obtian an equality of the properties in two directions.

Lubricating Oil Tests[1]

By Dr. W. H. Herschel[2]

THE object of tests of lubricating oil should be to determine suitability and durability, that is whether an oil is suitable for the purpose when new and whether it will be durable in service. It is important that these objects should be kept clearly in mind, since uniformity of test methods, which we all desire, can be secured only by uniformity of purpose in making tests

Gravity is sometimes used as a help in identifying a crude, but with the increased use of blends and of the Mid-Continent crude of mixed base the identification of crudes is becoming more and more difficult. It is also unnecessary and misleading, because there has never been adequate proof that just as good oils cannot be made from one crude as from another. Gravity is thus mainly of value as a correction in viscosity determinations, and it has been omitted from the Government specifications.

Viscosity is of prime importance in determining the suitability of an oil, but throws no light upon its durability. It tells nothing about deterioration in service but does enable an oil to be selected which will be suitable when new for the speed, pressure and temperature in the bearing where the oil is to be used. Apart from viscosity there is a property known as body or greasiness which determines suitability. There is no standard test for body, but it is known that with a sufficiently low speed and sufficiently intense pressure an oil of superior body will show lower friction. This has been proved in England by recent tests at very low speed,[3] and at the Bureau of Standards we have proved the same thing with high pressures by cutting off discs from a rod of cold-rolled steel. It should be noted that body determines suitability and not durability. In fact, the problem is to get as good a body as possible without too great a sacrifice of durability.

Coming now to tests for durability, we must consider how oils actually fail in service. Metallic contact or seizure is not necessarily an indication of deterioration of the oil, as it may be caused by the use of an oil of too low viscosity. The apparent failure of the lubricant, then would be due to underestimating the maximum temperature which would be reached in service, or to using an oil of a viscosity too near that of minimum friction. It is never safe to use an oil with a viscosity of minimum friction at the temperature of the bearing, but a more viscous oil must be used, the excess viscosity being necessary as a factor of safety against seizure.[4] If the factor of safety is made too low to decrease the friction, seizure may result, for which the lubricant is in no way to blame.

There are several emulsion tests in which the oil is subjected to a reproducible method of agitation with water, and the resistance to emulsification is measured by the rapidity of separation of the oil from the water after such treatment.[5] If an oil will meet this test satisfactorily, experience has shown that there will be no trouble from its emulsifying in use. Emulsion tests are also used to determine the purity of oils which are used in automobiles or in other machines where they do not come into contact with water. It has been found that if acid sludge is used as an impurity to contaminate a water-white lubricating oil, 0.1-per cent impurity is the maximum amount which could be used if the contaminated oil is to pass the requirements of a steam turbine oil. The selection of automobile oils is however a difficult problem which is by no means completely solved.

A test in common use is the carbon residue test which is based on the assumption that cracking of the lubricant takes place in an automobile cylinder. An examination of the cylinder deposit shows that this is only partly a cracked product, and that a large part is of an asphaltic nature and is therefore due to oxidation. There is, moreover, a possibility that some of the cracked product, real carbon, not the so-called carbon deposit, may be due to cracking of the fuel.[6] These considerations lead to the conclusion that the carbon residue test is inadequate alone and should be supplemented by an oxidation test. We are working at the Bureau of Standards on standardizing the oxidation test, the main difficulty being to design a reproducible oxidation oven.[7]

The owner of an automobile wants a test that will assure him the greatest mileage per gallon of oil. In other words, what is needed is a laboratory test that will indicate the consumption per horsepower-hour. The oil may evaporate in the course of circulation. To guard against excessive loss from evaporation we have, besides tests known as evaporation tests, the flash-point, which determines the volatility of the lightest fraction in the oil. The value of this last test is, however, greatly reduced by the fact that it gives no indication at all in regard to the amount of the light fraction present. The amount of the light fraction can be determined only by an evaporation test or a fractional distillation. While distillation of gasoline is common enough, the application of this test to lubricating oils has been delayed by the difficulty of making such a distillation without cracking. This difficulty has been overcome by the use of a high vacuum, the pressure being only 1.5 mm.

Crankcase oil may oxidize to such an extent that it will become more viscous after use, in spite of dilution from the fuel or from cracked products of the lubricant. If sediment is deposited it may clog the oil-passages and cut off the supply of lubricant so as to cause seizure. It is hoped by fractional distillation of new and used oils to determine what are the essential tests for automobile oils and how to interpret them. It is known that as a general rule the carbon residue test gives highest values for the most viscous oils, while, on the other hand, the oxidation test gives values for the least viscous. It is believed that by a comparison of fractional distillation tests of new and used oils it may be discovered whether the change or deterioration in an oil is mostly due to the light or to the heavy ends. If it is at the light end it would seem to indicate that the deterioration is by oxidation and that the oxidation test is the more important. If, on the other hand, the greater change in the fractional distillation curve should prove to be at the heavy end it would indicate that the carbon residue test is the more important.

In conclusion, I wish to emphasize the point that tests should not be made for identification of crude, as that proves nothing, but to determine the suitability when new or the durability in use. To believe that an oil will be good if made from a good crude is like believing that food will necessarily be good if made from good material. We all know better than to believe that.

Resume of Bureau of Standards Fuel Study

By H. C. DICKINSON[1]

ANNUAL MEETING PAPER   *Illustrated with* CHARTS

REGARDING the problem of the relation between distillation range and fuel economy, there has been considerable thought devoted recently to the relation of fuel end-point to economy. Mr. Howard's very interesting paper on the subject of Volatility of Internal-Combustion Engine Gasoline[2] shows conclusively, I believe, that provided we secure an intimate mixture of fuel-vapor and air, such a mixture will not condense at the temperatures of the intake with which we are working. However, over against this we have the evident fact that at present we are having crankcase dilution, excessive carbon deposit, low mileage and trouble with the ignition. All of these are manifestations of excess fuel consumption. Therefore, it seems that there must be some gap in the explanation somewhere; in other words, what we should get does not tally with what we do get. It was with the view of throwing a little light on this discrepancy that the Bureau of Standards undertook a brief series of experiments to rough out, so to speak, a line of investigation. Before taking up this question, however, I wish to present a few observations on another subject.

A question often raised and which apparently has not been definitely answered regards the effect of compression on the dryness, or dew point, of the mixture of fuel and air. To develop definite figures on this subject, we have looked up such information as is available in published form and submit this in the form of a set of curves.

Fig. 1 shows that gasoline vapor compresses "dry." As Mr. Howard pointed out, each of the components in commercial gasoline has a definite vapor pressure at a definite temperature and, above some particular temperature, each one of the components will exist in the form of a vapor when mixed with air in any given proportion. Taking the rough assumption that the proportion of vapor to air is about 2 per cent by volume, we have at the left of the diagram a series of curves which represent, for several of the substances for which figures are available, the relation between the vapor pressure of the substance and the temperature, and at the right, adiabatic compression curves are plotted in millimeters of mercury and degrees centigrade, showing the pressures and temperatures for these same substances when mixed with air in the foregoing proportion. The various curves are plotted for different initial temperatures. The diagram is drawn so that at any point where the left-hand curves representing the various substances are above the adiabatic compression curves, the mixture will be dry; if they are below, the fuel will condense. The point of particular interest is that the adiabatic compression of a mixture

invariably makes it very markedly dryer, so that there is an opportunity for vaporizing fuel to a considerable extent in the cylinder, due to compression alone. Thus a fog mixture of decane and air in the proportion of 1 to 15 and at 32 deg. fahr. if compressed to slightly less than half its volume will become dry. If the compression were to take place at a constant temperature rather than adiabatically, the result would be entirely different, the fuel being condensed rather than evaporated.

FUEL CHARACTERISTICS AND ECONOMY

To throw some light on the relation between fuel characteristics and economy experimentally, we undertook a brief series of experiments with the equipment which was used for the report presented by Mr. James[3] last summer. I present the results with the belief that they do not represent truly what is average practice, but that they may point out certain limits which have not been well recognized before. The equipment referred to is a six-cylinder engine coupled with a dynamometer. It has a hot-spot manifold, equipment for measuring and controlling temperatures and pressures and for making such measurements as are desired, including measurements of acceleration.

I assume that typical driving conditions can be represented by a car speed of 20 to 25 m.p.h. and a horsepower which about corresponds to the average load of a car on the level at that speed. Typical conditions also involve very frequent acceleration; accelerations, for instance, of from 10 to 30 m.p.h. and, under these conditions, with an intake air temperature which is likely to be about 60 to 70 deg. fahr. and a normal amount of heat on the intake-manifold. In these experiments, the hot-spot on the manifold was cut out by blanking it off with a piece of asbestos, inserted between the intake and exhaust-manifolds. The immediate object of the experiments was to determine the difference, if any, in the amount of fuel burned to perform a definite amount of service under typical driving conditions as represented above, for three grades of gasoline; first, with aircraft gasoline, then with commercial gasoline and finally with aviation gasoline containing about 15 per cent of kerosene.

Two main types of experiments were undertaken. These were (a) steady runs to determine the rate of fuel consumption under load conditions, at about one-fifth the maximum mean effective pressure and a speed of 1200 r.p.m. and (b) a series of repeated accelerations from 10 to about 30 m.p.h. In each case the fuel consumption was recorded. The constant-speed runs were all made at the same speed and load and for the same length of time with special care exercised as to the conditions of air, water and oil temperature, so that the total number of horsepower hours was as nearly as possible the same in all cases.

The acceleration runs each consisted of a series of accelerations following a period during which the engine idled with a closed throttle. The idling speed and adjustment and the stop to which the throttle was opened on acceleration were carefully regulated to assure the same engine speed on idling and the same throttle opening on acceleration for all runs. The idling and acceleration periods followed the same scheduled sequence and were of the same duration in all cases.

The load on the dynamometer depended upon the speed as determined by the characteristics of the dynamometer, the torque being nearly proportional to the speed. The control rheostats were adjusted the same in all cases; hence, the total horsepower-hours developed in all the acceleration runs were substantially the same. A watt-hour meter was not available but would have been desirable as a check on the equality of power output.

The schedule for each acceleration run was as follows:

(1) Adjust throttle to idle at 500 r.p.m. and adjust acceleration stop to give a speed of 1500 r.p.m.
(2) Idle for 30 sec.
(3) Open throttle to stop and observe time required to reach 1200 r.p.m.
(4) Maintain this speed for remainder of first 60 sec.
(5) Close throttle to idling position at 60 sec.
(6) Open to acceleration position at 90 sec.

The series was repeated five times.

The dynamometer equipment includes two fuel tanks arranged so that they can be supplied with different fuels and the supply to the engine quickly changed from one to the other.

In these experiments two of the three fuels, first aviation gasoline and commercial were supplied and a single run, as described above, was made, first with aviation gasoline with a selected carbureter adjustment and repeated with commercial gasoline and the same adjustment; then the carbureter adjustment was changed to a leaner one and a run taken with commercial gasoline, then with aviation gasoline and the same adjustment. In this way five values of mixture ratio were run, the fuels being alternated between each pair of runs. A series of comparisons were similarly made between the aviation gasoline and this fuel plus 15 per cent of kerosene.

The results of these runs have been rather carefully tabulated, but an examination of the tabulation yields one result, namely, that for the conditions here adopted there is no significant difference in the total amount of either of the three fuels consumed, reckoned in pounds, to deliver the same amount of horsepower hours under the same conditions. I wish to repeat that I do not believe that these observations show that the fuel consumption in service is independent of the fuel composition. They do show, however, that the induction system of the particular engine used for these tests was unusually good, as the intake temperature was only about 125 deg. fahr.

What Is Detonation?

There has been much discussion as to precisely what the phenomenon of detonation really amounts to physically; as to the precise physical performance inside an engine cylinder when it develops the sound which we call detonation. Some of our colleagues at the Bureau of Standards have been inclined to question very carefully every proposal which has been set forth. Mr. Sparrow suggested sometime ago that he wanted to prove whether what we recognize as detonation or fuel knock could not
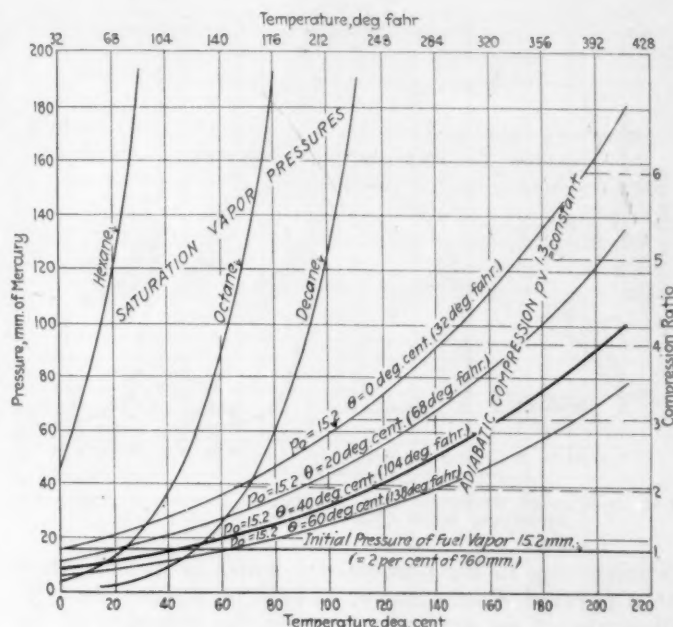

Fig. 1—Series of Curves Showing That Gasoline Vapor Compresses Dry

after all be an aggravated piston slap. We have a one-cylinder Liberty engine which has served many experimental purposes. This engine was fitted with a piston about 1/10 in. too small in diameter which produced a most aggravating slap, as was intended. There being no doubt about the presence of the piston slap, we stood some chance of finding whether the detonation and the piston slap were the same or not. After some adjustment, it was possible to get detonations in conjunction with the piston slaps. The two things are distinguished very easily and no other proof seems necessary that they are entirely independent.

Following these observations we became interested in recording some of the facts, or apparent facts, which can be established with regard to the phenomena of detonation, particularly those which can be verified by physical measurements. The one-cylinder Liberty engine is admirably adapted for such observations as the parts can readily be replaced and it can be modified to meet experimental conditions. The cylinder at present in use is fitted with openings for three spark-plugs, permitting at least one to be used for experimental purposes such as mounting an indicator or a window for looking into the cylinder without interfering with ignition. When observing the conditions which affect detonation, it is desirable to make these observations under conditions such that detonation is just on the verge of occurrence or nonoccurrence. Under these conditions the phenomenon is most sensitive to changes in conditions. Accordingly, all observations discussed hereafter were made with the engine throttled to about 60 lb. mean effective pressure and a speed of approximately 1100 r.p.m. Under these conditions, the cylinder developed 10 to 11 hp. and detonation was easily brought in or prevented by slight changes in the conditions of operation. Commercial gasoline was used in most of these experiments.

One of the most significant features of the phenomenon to me is its discontinuity. By discontinuity I mean that the detonation knock is as definite a physical thing as the explosion; it either occurs or it does not occur. When it occurs it occurs with considerable violence; and when it does not occur it is entirely absent. In this sense, there
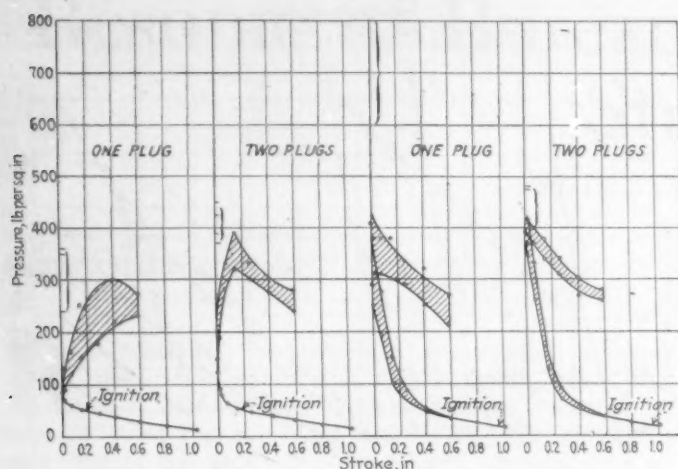
FIG. 2—CURVES SHOWING THE MAXIMUM EXPLOSION PRESSURES
DEVELOPED WITH ONE AND TWO SPARK-PLUGS

is something in the phenomenon which is in the nature of a physical discontinuity; it fires or it does not. To illustrate, if we gradually increase the intensity of the spark in a cylinder which is being fed with fuel mixture, the charge will not fire as long as the spark is too weak, but at some point it will begin to fire irregularly; some strokes will be accompanied by an explosion, while others will not. Similarly as regards detonation, some strokes are accompanied by it and some are not, and it is usually very easy to distinguish between them, although the intensity can be varied widely.

For the most part, observations were made with the conditions substantially constant, except for changes in the timing and changes from one to two spark-plugs. The water temperature was maintained at about 70 to 75 deg. fahr. constantly; the mixture ratio was kept constant under all conditions, and carefully checked to see that it did remain constant. It soon developed that it was very easy to get a perfectly definite detonation with one spark-plug and no detonation with two spark-plugs, all other conditions remaining fixed. That has been noticed many times and is explained naturally by the theory of the detonation waves. But, carrying it further, Mr. Sparrow showed that it is almost as easy to get detonation with two spark-plugs, while not with one spark-plug. That is not so simply explained on the basis of the accepted detonation-wave theory, although the fact may prove to be consistent with this theory.
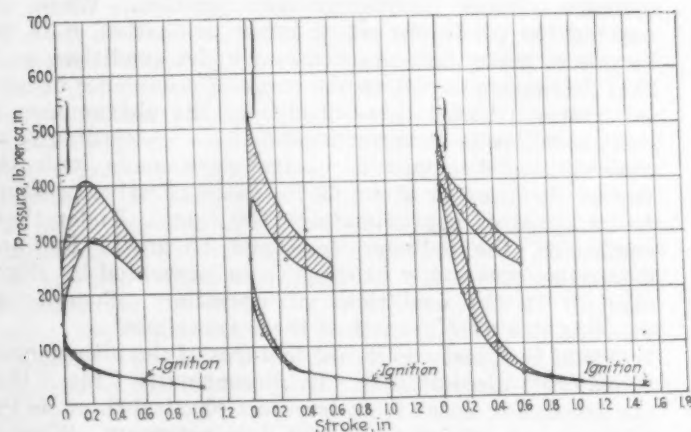

FIG. 3—A SERIES OF SIMILAR CURVES TAKEN WITH THE SINGLE
SPARK-PLUG
The Curve at the Left Represents the Maximum Power, That in
the Center the Maximum Detonation and the One at the Right the
Effect of a Moderate Preignition

The most obvious conclusion from these experiments is that, whatever the nature of detonation, it is largely dependent upon the timing of the explosion with respect to the position of the piston. This does not mean necessarily the timing of the ignition spark, but rather the time at which the maximum rate of burning takes place. For instance, when firing from two spark-plugs at opposite sides of the cylinder, the maximum rate of burning will occur a much shorter time after ignition than when firing from a single spark-plug. If, therefore, the ignition time is the same in the two cases, firing from two plugs instead of one will in effect advance the ignition and vice versa.

Thus, if the ignition timing in the present experiments was such as to produce detonation with two spark-plugs, cutting out one plug had the effect of retarding the time of burning sufficiently to prevent detonation. On the other hand, if the timing was such as to produce detonation with one spark-plug, cutting in a second plug had the effect of advancing the time of burning and preventing detonation by this means. These effects are shown in the several illustrations described below.

Another phenomenon noticed is the fact that the temperature of the jacket water, or the heat lost to the jacket, was materially affected by the fact of detonation or not. The intake water for this engine was kept at a nearly constant temperature and the rate of flow was substantially constant; consequently, it was easy to determine roughly the amount of heat supplied to the water-jacket by measuring the temperature of the outlet water and, under all conditions where detonation was produced, a very marked rise of temperature in the jacket developed. I believe that the actual amount of heat supplied to the water-jacket was in some cases almost 30 per cent greater when detonation was produced than when it was not produced. Accompanying that increase in heat to the jacket there was usually a small dropping off in the mean effective pressure, but the dropping off in the mean effective pressure by no means accounted for the actual extra heat lost. The source of the apparent extra energy, as well as the general effect of detonation on heat distribution, might be worth careful consideration.

FURTHER DETONATION EXPERIMENTS

Following the foregoing experiments, an indicator was mounted on the cylinder and a series of indicator cards were taken under varied conditions to throw more light on the exact conditions accompanying detonation. It should be borne in mind that all these experiments were carried out at pressures which were just on the verge of detonation. Most of the observations which have been made along this line have been at full load and under conditions where the maximum pressures often were considerably higher than is necessary to produce this phenomenon. With compressions barely high enough to produce detonation, it might be expected that the phenomenon would be much more sensitive to pressure and ignition timing than if we were working under less carefully controlled conditions. Even at these compressions, maximum pressures in the cylinder of far above 1000 lb. per sq. in. were developed repeatedly. Incidentally, the pressure on the wrist-pin was somewhat over 8000 lb. per sq. in.; I believe it was 10,000 lb. per sq. in. in some cases.

The curves in Fig. 2 were plotted in terms of the distances of the piston from its center position, in tenths of an inch. The point of ignition is shown on the various curves. The shaded area represents the area between

which the maximum and the minimum pressure occurred in any cycle. The indicator we are using is one which enables us to plot the maximum, minimum and intermediate pressures in the cylinders, for each position of the crankshaft. The brackets to the left indicate the range of maximum pressures which were measured, independent of the position in the stroke. In the two curves at the left, the ignition time was the same but the time of burning was advanced in the second case due to ignition by two spark-plugs instead of one. The next curve to the right was produced with one spark-plug. The much higher peak pressure should be noticed in this case. The detonation knock was present in this instance and the bracket at the top shows the presence of very high maximum pressure, accompanied by very marked detonation knock, in fact, an intolerable noise. The curve farthest to the right represents the absence of
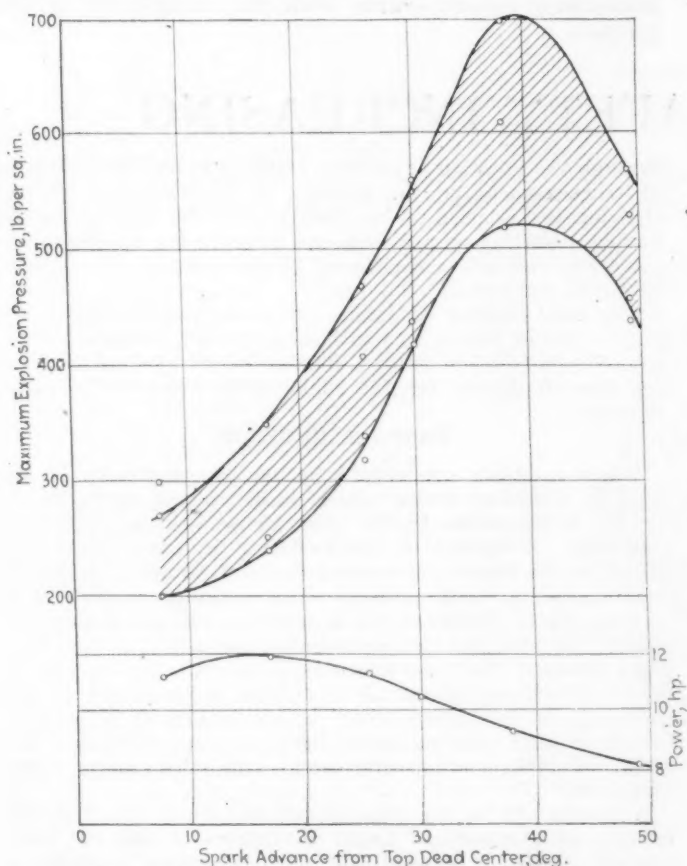

FIG. 4—CURVES SHOWING THE RELATION BETWEEN SPARK TIMING AND THE MAXIMUM PRESSURES REACHED IN THE CYLINDER

detonation with two spark-plugs, the ignition timing being the same as for the previous curve. Ignition is obviously too early in this case as shown by the shape of the curve at the maximum pressure, but little or no knock was observed.

Fig. 3 shows similar curves that were all taken with one spark-plug. The curve toward the left represents normal burning. The point of ignition is 0.6 in. below top dead-center. The first curve represents the maximum power and the second represents the maximum detonation with the single spark-plug. In this case the maximum pressure range is 500 to 700 lb. per sq. in., the normal compression range being 375 and 525 lb. per sq. in. This curve represents a marked loss of horsepower, as compared with the former. The third curve represents the effect of moderate preignition; then the
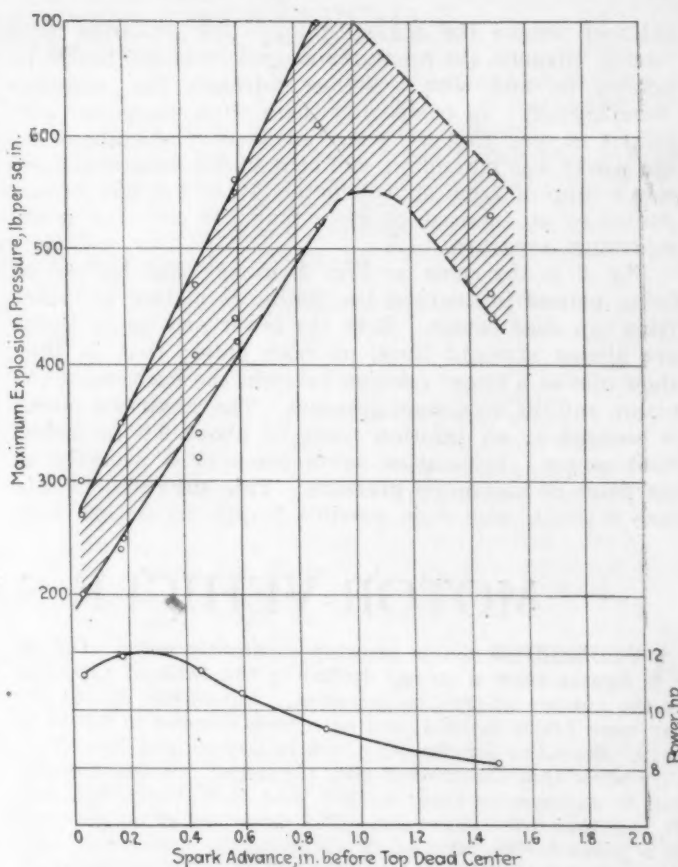

FIG. 5—A SIMILAR SET OF CURVES TO THOSE GIVEN IN FIG. 4 EXCEPT THAT THE TIMING IS PLOTTED IN INCHES FROM THE TOP DEAD CENTER INSTEAD OF DEGREES

pressure drops during the dead-center period, due to cooling of the cylinder walls or to leakage. This drop of pressure during the compression period may be due partly to actual leakage and partly to cooling of the charge, which is at a very high temperature. It should be noted that the maximum pressures as indicated by the brackets are only about the same as in normal operation, as shown by the first of the three curves, and the knock is no more pronounced.

Fig. 4 is plotted to show the relation between spark timing and the maximum pressures reached in the cylinder, also the power output. The upper curve represents the range of maximum pressures which occur in the
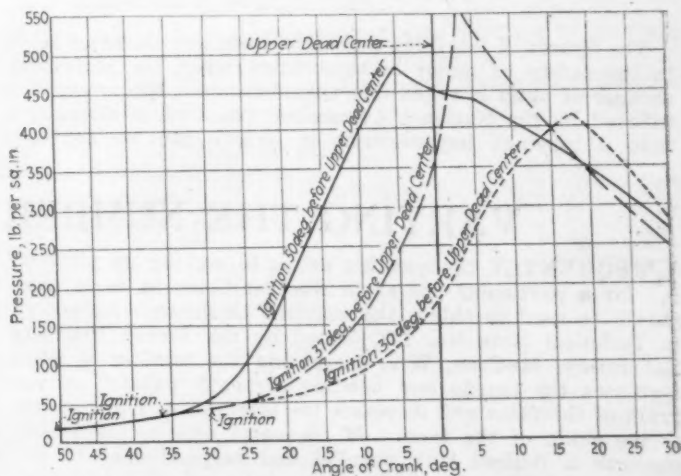

FIG. 6—CURVES SHOWING HOW A VARIATION IN THE POINT OF IGNITION CHANGES THE MAXIMUM EXPLOSION PRESSURE

cylinder versus the spark timing. For instance, at a 20-deg. advance, the pressures ranged from 265 to 390 lb. per sq. in. and with a 40-deg. advance, the pressures were highest. In comparing these with the power output, it is seen that a 15-deg. advance or slightly more, the power was maximum, and at a 40-deg. advance, there was a drop of from approximately 12 to 8½ hp., accompanied by an increase of more than 100 per cent in the maximum pressure.

Fig. 5 is the same as Fig. 4, except that instead of being plotted in degrees, the timing is plotted in inches from top dead center. Both the lower and upper limits are almost straight lines, on both sides; that is, they show almost a linear relation between the position of the piston and the maximum pressure. The maximum power is secured at an ignition point of about 0.3 in. below dead center. Detonation takes place most severely at the point of maximum pressure. This suggests, in this case at least, why it is possible to get detonation with two spark-plugs and not with one spark-plug, and vice versa, depending upon the timer setting.

Fig. 6 gives the data plotted in Fig. 3, in pressure-time coordinates. Hence the curve to the left represents normal conditions, the middle curve the maximum detonation as produced by change of spark timing alone, and the right-hand curve shows the characteristics of too early ignition.

The foregoing are only a few of the facts and fancies regarding the phenomenon of detonation. There is much more that we think we know and still more that we think we can see and hear. We may never acquire a complete and definite knowledge of the real nature of the phenomenon, and it might be of little practical value if we do. So long as such an obvious and important problem remains unsolved, we can hardly cease to look for its solution and hope that when found the solution will be of importance commensurate with the complexity of the problem.

MOTOR-VEHICLE SAFETY INCREASING

AUTOMOBILE use is growing constantly safer. Official figures show a steady decline in the ratio of fatalities to the number of cars in operation. Automobile deaths per car were 0.0025 in 1914, and have been reduced to 0.0013 in 1919. Statistics for the year 1920 in Detroit and New York City show that the former city registered one less fatality due to automobiles than in 1919, and New York's toll was 21 less than the 1919 mark. The reduction of 50 per cent in 5 years in the ratio of fatalities to the number of cars shows that the public is quickly adapting itself to the problems of congestion, and continued progress in motor-vehicle safety is confidently looked for.

DEATHS CAUSED BY AUTOMOBILES IN THE UNITED STATES FROM 1914 TO 1919

Year	Number of Automobile Deaths per Car	Total Number of Automobile Deaths	Registration of Cars	Cars per 1000 Population	Automobile Deaths per 1000 Population
1914	0.0025	4,231	1,711,339	17	0.0428
1915	0.0024	5,928	2,445,664	24	0.0591
1916	0.0021	7,397	3,512,996	34	0.0725
1917	0.0019	9,184	4,983,340	48	0.0887
1918	0.0016	9,672	6,146,617	59	0.0919
1919	0.0013	9,827	7,558,848	71	0.0936

The figures of fatalities show that some gain is being made in the safety of motor transportation when the increasing number of units is taken into consideration. Moreover, it is believed by the National Automobile Chamber of Commerce that a constant improvement in safety can be achieved through the adoption of uniform traffic laws and the education of truck owners on the dangers of overloading. Figures showing the relation of car fatalities to the various factors having a bearing on accidents are given in the accompanying table and indicate a decline of 50 per cent in the ratio of fatalities per car.

The total number of deaths caused by automobiles in the entire United States was estimated by the National Workmen's Compensation Service Bureau which applied the Census Bureau figures for the registration area to the entire country.

PROPOSED REMEDIES

Many accidents are caused by the varying rules of the road in different States which leads to the confusion of drivers in interstate traffic. The Motor Vehicle Conference Committee, composed of car builders, dealers, owners and allied bodies urged a proposed uniform vehicle law before legislatures this past winter. This measure contains provisions which, if adopted by the states, will set a standard code for driving and thereby enhance the safety of the interstate drivers. This law also would require every vehicle to carry certain equipment all of which is conducive to the safety of the travelling public. This equipment consists of brakes in good working order, horns or other signalling devices, regulations concerning lamps and other safety specifications.

Attempts will be made to educate the truck owner on the dangers of overloading. Legal restrictions on this are helpful, but evasion is so easy that the final appeal must be to the user. Overloading injures the truck and shortens its life. Overloading is highly dangerous to the driver and to pedestrians as the brakes of a vehicle cannot function at 100 per cent efficiency when the truck is carrying more than its rated burden.

VARYING THE NUMBER OF PLIES IN PLYWOOD

FREQUENTLY the question arises in making up plywood for a particular use as to whether three or more plies should be used to obtain the required thickness. According to Technical Note No. 132, issued by the Forest Products Laboratory, Madison, Wis., increasing the number of plies decreases the tensile and bending strength parallel to the grain of the faces and increases the strength at right angles to the grain of the faces. If the same bending or tensile strength is desired both parallel and perpendicular to the grain of the faces, increasing the number of plies will tend to give this result. If on the other hand greater strength is required in one direction than in the other a three-ply panel is preferred since plywood with a large number of plies while stronger at right angles to the grain of the faces cannot be as strong parallel to the grain of the faces as three-ply wood. Where great resistance to splitting is required as in plywood that is fastened along the edges with screws and bolts and subjected to forces through the fastenings, a large number of plies affords a better fastening.

A glued joint is more likely to fail when thick laminations are glued with the grain crossed than with thin layers and this weakness exists in plywood with thick plies.

DATA ON ILLINOIS TRACTORS

THE data used in this discussion were taken from a tractor survey made by the Division of Farm Mechanics, University of Illinois, and comprise records kept by farmers on 68 tractors. The tractors were divided into three groups, namely, two-plow, three-plow and four-plow machines. Table 1 shows this grouping with the rating and number of tractors considered. It must be remembered that the figures given for each group are the average for all tractors in that group.

TABLE 1—THE TRACTORS GROUPED BY RATINGS

Number of Plows	Rated Horsepower	Number in Group	Total Number
2	6–12	4	
	8–16	8	
	9–18	5	17
3	10–20	23	
	12–25	21	44
4	15–30	3	
	18–36	3	
	20–40	1	7

The size of farm upon which the tractor can be used profitably in the corn belt varies a great deal with the system of farming. A 160-acre farm is considered about the minimum in the corn belt for the profitable use of a tractor, but in one instance a three-plow tractor was operated on a 100-acre farm at a lower total annual expense than the horses which it replaced.

TABLE 2—SIZE OF FARMS AND ACREAGE IN CROPS

Size of Tractor	Two-plow	Three-plow	Four-plow
Size of Farm, acres	258	298	309
Planted Area, acres	186	203	210
Planted Area, per cent	72.0	68.3	68.0
Corn Area, acres	89	85	82
Corn Area, per cent	48.0	46.7	39.0
Small Grain Area, acres	81	97	108
Small Grain Area, per cent	43.5	47.8	51.5

Table 2 shows the size of the farms and the acres in corn and small grain. A study of this table will show a decreasing percentage in acres devoted to crops as the size of the farm increases; also a decrease in the acreage of corn and an increase in the acreage of small grains as the size of the tractor increases. The average size of the farms on which two-plow tractors were used was 258 acres, and 298 acres with the three-plow tractors, representing but a small difference between the average size of the farms on which the different sized tractors were used.

It is generally conceded in these reports that soil packing does not result harmfully. Only four of the 68 operators reported harmful results from packing; nine reported harmful results when the soil was wet.

NUMBER OF DAYS TRACTOR IS USED

There is much agitation at the present time to put the tractor to a greater variety of uses on the farm. Table 3 shows the number of different days, hours, and hours per day that the various tractors were used. At a glance we would say that the tractor is not used enough days to make it pay. Thirty to fifty days of use will be about the average where the tractor is used on the farm only. It must be kept in mind that the tractor is used mainly during the period of peak loads which occur in April, May, June, October and November. At other times the horses that must be kept on the farm can take care of most of the work. The comparatively small number of hours the tractors were used per day, on the average, is not an indication of inefficiency, for in almost every case these days were full days.

It is interesting to note in Table 3 that there is a slight decrease in the percentage of actual tractor trouble in the field, as the size of the tractors increases. The individual records show that, contrary to general opinion, the kerosene-burning tractors were as free from trouble as those burning gasoline.

The different operations performed by these tractors were as follows:

Traction Work	Belt Work
(1) Plowing	(1) Threshing
(2) Discing	(2) Silo Filling
(3) Harrowing	(3) Shelling Corn
(4) Drilling	(4) Shredding Corn
(5) Harvesting	(5) Baling Hay and Straw
(6) Cultivating Corn	(6) Hulling Clover
(7) Pulling Corn Pickers	(7) Grinding Corn
(8) Pulling Hay Loaders	(8) Running Grain Elevator
(9) Hauling Manure	(9) Sawing Wood
(10) Pulling Posts	
(11) Moving Building	
(12) Grading and Dragging Roads	
(13) Grading Ditches	

All of these operations can be handled profitably with the tractor, if the machine is of the proper size for the particular job.

An idea of the work done per hour by the tractors can be gained from a study of Table 4. The low figure in the case of discing with the four-plow tractor is due to an insufficient number of discs for a full load.

TABLE 4—WORK PER HOUR

Size of Tractor	Two-plow	Three-plow	Four-plow
Plowing, acres per hr.	0.733	0.813	1.191
Discing, acres per hr.	1.470	2.050	1.790
Harvesting, acres per hr.	1.890	2.170	2.470

Very favorable reports were given as to the reduction of the hired-help bill; 7 per cent of the operators reported no effect, but indicated more time available for odd jobs; 5 per cent reported a saving of from 10 to 50 per cent in hired help.

REPLACEMENT OF HORSES

In studying this problem there are two viewpoints to be considered, namely, the number of horses displaced by the tractor and the increase in crop acres per horse, both of which are shown in Table 5. The latter method is the most logical

TABLE 3—DAYS TRACTOR WAS USED AND HOURS OF TROUBLE IN THE FIELD

Size of Tractor	Two-plow	Three-plow	Four-plow
Days Used	34.4	35.0	55.0
Hours Used	233	255	342
Use per Day, hr.	6.77	7.28	6.21
Trouble in Field, hr.	9.04	7.40	10.60
Time Lost on Account of Trouble, per cent	3.87	2.90	3.09

TABLE 5—HORSES REPLACED AND INCREASE IN CROP-ACRES PER HORSE

Size of Tractor	Two-plow	Three-plow	Four-plow
Original Number of Horses	8.3	10.4	11.7
Horses Used after Tractor was Purchased	5.6	7.2	8.2
Horses Replaced by Tractor	2.7	3.2	3.5
Crop-Acres per Horse before Tractor Was Bought	22.4	19.5	17.9
Crop-Acres per Horse after Tractor Was Bought	33.2	28.2	25.6
Increase in Crop-Acres per Horse, per cent	48.3	44.5	43.0

TABLE 8—GASOLINE, KEROSENE AND OIL CONSUMPTION

Size of Tractor	Fuel Consumption gal. per hr.		Fuel Consumption per Acre Plowed, gal.				Fuel Consumption per Acre Disced, gal.				Fuel Consumption per Acre Harvested, gal.			
	Gasoline	Kerosene	Gasoline	Oil	Kerosene	Oil	Gasoline	Oil	Kerosene	Oil	Gasoline	Oil	Kerosene	Oil
Two-plow	1.490	1.870	1.860	0.144	3.090	0.251	1.170	0.096	1.560	0.080	0.790	0.057	0.850	0.073
Three-plow	1.870	2.260	2.450	0.152	2.760	0.190	0.900	0.050	1.270	0.081	0.700	0.053	1.000	0.072
Four-plow	2.640	2.360	2.700	0.208	1.450	0.077	1.500	0.125	0.140	0.065	0.890	0.050	0.700	0.024

basis for comparison. Some of the farmers did not dispose of any horses, but increased the crop acreage per horse. An average of all the farmers using tractors shows an increase from 20 crop-acres per horse where horses were used to 29 crop-acres per horse where tractors and horses were used, an increase of 49.5 per cent. Again we find that as the size of the tractor increases the crop-acres per horse decreases. Where two-plow tractors were used there were 33.2 crop-acres per horse, while with the four-plow tractors this was reduced to 25.6 crop-acres per horse, indicating a lessening of the utility of the horse. These farms were average corn-belt farms, growing corn and small grains. Corn takes almost twice as much horse labor per acre as small grains, and it is logical to conclude that the larger farms were not making as efficient use of their horse labor as were the smaller farms.

TABLE 6—COMPARATIVE COST OF TRACTORS AND HORSES

Size of Tractor	Total Annual Cost of Tractor	Horses Replaced	Cost of Keeping Horses
2	$382.62	2.7	$353.00
3	388.18	3.2	419.00
4	637.99	3.5	457.00
5	937.08	2.0	262.00

Table 6 brings out some very interesting results concerning the tractor and horse question. The following values were used for the tractor as a basis of comparison: Depreciation 20 per cent, interest on investment 6 per cent, gasoline 23 cents per gal., kerosene 13.5 cents per gal., and actual cost of repairs. No credit was allowed the tractor for the belt work done, the hired help which it displaced, and no depreciation was allowed on the horses.

The cost of horse labor which is based on cost accounts kept by the Farm Management Department of the University of Illinois during 1917 is given in Table 7.

TABLE 7—COST OF KEEPING A HORSE IN 1917

Feed	$103.18
Labor	11.80
Interest	7.79
Shelter	2.91
Harness	3.72
Miscellaneous	1.54
Total	$130.94

In view of the above considerations the three-plow tractors operated at a lower annual cost than the horses which they replaced. If we were to consider the belt work done and the hired help which the tractor displaced, the figures would be much more in favor of the tractor. The above statements are upheld by the fact that 57, or 88.7 per cent of the operators reported that their tractors had been profitable investments.

The kerosene, gasoline and oil consumption of the tractors is shown in Table 8. In practically all cases more kerosene than gasoline is used per unit of work; 20 per cent more kerosene than gasoline. There is a tendency toward less kerosene consumption per unit of work as the size of the tractor increases. The oil consumption for kerosene machines is greater than for gasoline tractors in all operations except discing. The oil consumption of the different machines varies greatly, since much is dependent upon the individual operators.

REPAIRS

The records show a slightly lower repair bill for kerosene burning tractors. The average age of the 68 tractors considered was 2.3 years, and the average repair bill 3.4 per cent of the original cost of the tractors. The tractors range in age from 1.25 to 4.60 years. A marked increase in the repair bill can be expected as the tractor becomes older. At the present time the average life of a tractor is considered to be about 5 years. Much can be done to reduce the repair bill and lengthen the life by careful care and operation.

TABLE 9—TOTAL ANNUAL COST OF TRACTOR OPERATION

Size of Tractor	Two-plow	Three-plow	Four-plow
Fuel	$112.86	$90.50	$173.70
Lubricants	31.93	20.85	56.72
Repairs	34.29	32.60	14.16
Miscellaneous Items	2.00	4.70	5.11
Depreciation	170.80	202.82	329.40
Interest	30.74	36.71	58.90
Total	$382.62	$388.18	$637.99

The total annual cost of operating the tractors is given in Table 9. It should be noted that fuel and depreciation are the big items of the operating cost. The low total fuel consumption for the three-plow tractors is due to the fact that several of the machines were used very little. The records tend to show that there is a general tendency for increased cost of operation in the gasoline burning machines, while in kerosene burning machines the tendency is to reduce the cost. On corn-belt farms of 160 acres or more the proper sized tractor will operate at a cost equal to or less than that of the horses it displaces.—R. I. Shawl in *Orange Judd Farmer*.

LARGEST INTERNAL-COMBUSTION ENGINE VESSEL

THE largest vessel fitted with internal-combustion engines now in service was recently completed at Krupps' yard at Kiel, Germany. This is the motor tank-vessel Zoppot. She has a dead-weight carrying capacity of 15,000 tons, and is 525 ft. in length, with a beam of 66½ ft. She is equipped with two Diesel engines, each of 2000 b.hp., constructed by Krupps. They are of the two-stroke single-acting type, with six cylinders 22⅝ in. in diameter and having a 39⅜ in. stroke, and are very similar in design to engines constructed by the same builder before the war. Although most European oil-engine builders adopt port scavenging now for two-cycle engines, in the Krupp engines the old arrangement of scavenging by valves in the cylinder cover is retained.—*Engineering Supplement, The Times* (London.)

National Advisory Committee's 5-Ft. Wind Tunnel

By F. H. NORTON[1]

Illustrated with PHOTOGRAPHS AND DRAWINGS

IN the spring of 1919 work was started on a 5-ft. wind tunnel for the National Advisory Committee for Aeronautics at Langley Field, Va., and in the spring of 1920 the tunnel was completed and ready for calibration and for conducting tests. This tunnel has now been in operation for about one year and during that time new apparatus and equipment have constantly been added to increase its efficiency and usefulness. While the tunnel is not as large as some that are now in use, it has, it is believed, the highest useful speed of any wind tunnel in the world, that is, it maintains a high velocity flow which is steady in speed and direction, and it possesses satisfactory means for measuring the forces on models at the highest velocities. At present, useful speeds up to 120 m.p.h. can be attained; but, as the propeller was originally designed for other conditions, it is estimated that with a new and higher-pitch propeller a maximum speed of 140 m.p.h. can be reached. Testing models at such high velocities is not a simple matter and a number of new methods and devices had to be developed to accomplish this successfully. For this reason a large portion of the time that the tunnel has been in active operation has been occupied in carefully studying the aerodynamic properties of the tunnel and in constructing apparatus for holding models at the high velocities which can be reached so that only in the last few months has the tunnel been devoted continuously to research work. From now on, the work of the tunnel will be devoted almost exclusively to tests on thick airfoils, including an investigation of their pressure distribution, and to study the stability of model airplanes.

TUNNEL AND BUILDING

The wind-tunnel building, which is constructed substantially of brick and steel, is approximately 92 ft. long, 43 ft. wide, and 28 ft. high at the eaves. In Fig. 1 is shown a longitudinal section of the building and tunnel giving the principal dimensions of the structure. A heavy concrete foundation runs the whole length of the tunnel and a separate foundation is used for the power-plant, so that any vibrations which may be set up by the propeller or motor are not directly transmitted to the tunnel or balance. The interior of the building is smooth and free from obstructions so that the return flow of air from the tunnel will be disturbed as little as possible. Large doors at one end of the building allow the circulation of outdoor air for cooling the building in summer, which is necessary because of the rising temperature due to the power loss in the tunnel at the higher speeds, although, of course, these doors cannot be open while the actual tests are being carried on, owing to possible disturbances from the wind. Besides the main room for the tunnel there are several small rooms for offices in the building.
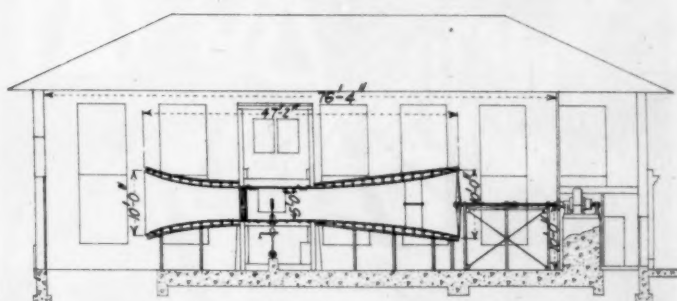
FIG. 1—LONGITUDINAL SECTION OF THE WIND-TUNNEL BUILDING AND THE TUNNEL

The tunnel itself is of the venturi type with a continuous throat of circular section, and there is an air-tight experimental chamber built about the working section in order that small holes may be opened into the tunnel while it is running, without disturbing the airflow; and this chamber has proved of great convenience in much of the work. The tunnel expands, as shown in Fig. 1, from the 5-ft. diameter working section to a diameter of 10 ft. at the mouth of the entrance and exit cones. This type of tunnel was selected after a considerable amount of investigation had been made upon a model tunnel 1 ft. in diameter, by measuring its efficiency and steadiness while varying many of its characteristics, especially the form of the cones, the type of the experimental chamber, the diffusers and honeycombs.[2] It will be noted that, contrary to usual practice, no diffuser is used in the return flow, and this is because the gain in steadiness from its use was found to be very slight on the model, while the cost of the full-sized diffuser would be considerable. Taking into consideration the aerodynamic efficiency of the tunnel, the cost of construction and the steadiness of the air flow, this type of tunnel was considered to be the best for the proposed investigations, although for some classes of work a larger diameter and slower speed tunnel would be more advantageous.

The cones of the wind tunnel as shown in Fig. 2 are supported from a concrete foundation by heavy steelwork and the surface of the cones is planked with cypress with the inside highly polished. This construction may at first seem unduly heavy but when it is realized how great are the vibrations set up by the higher wind speeds and the necessity for having the cones remain perfectly true, it is evident that such a construction is quite justified.

The experimental chamber, which is about 10 ft. long, 14 ft. wide, and 23 ft. high, is built around four concrete columns of very massive construction to withstand the heavy pressures, in some cases as much as 80 lb. per sq. ft., that arise during the high-speed runs. The lower story of the experimental chamber contains the National Physical Laboratory balance and the controlling devices for the air speed, while the upper story contains the propeller dynamometer and wire type of balance. The
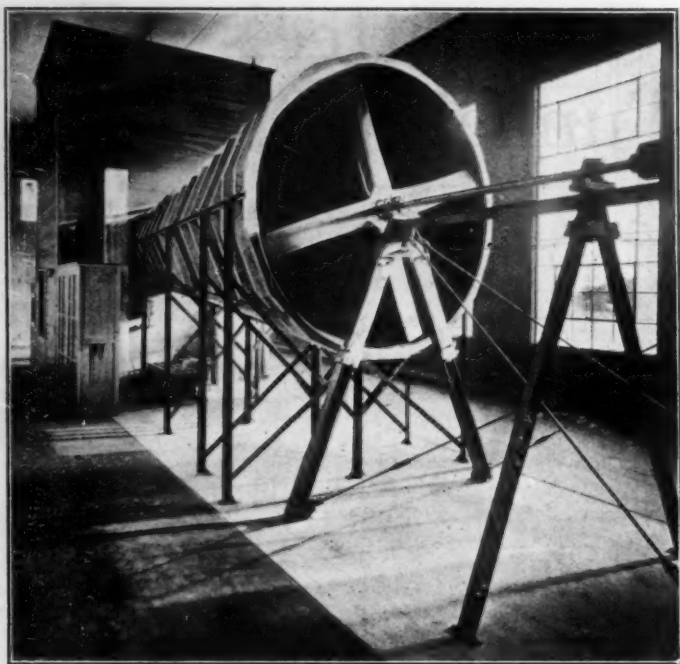
FIG. 2—GENERAL VIEW OF THE TUNNEL

chamber is entered either by a large door when the tunnel is not running, or when it is necessary to enter with a difference in pressure, an air lock is provided which consists of two small doors with air valves. Adjustments are made on the model through large doors which can be opened in the throat of the tunnel, these doors being curved to fit the section of the throat. In order that the model may be inspected during a test, there are
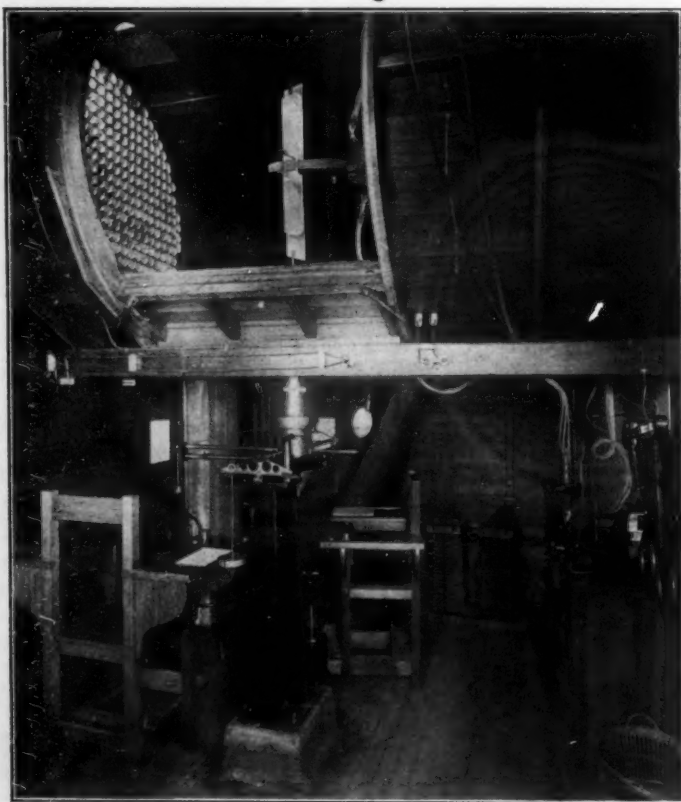

FIG. 3—INTERIOR OF THE EXPERIMENTAL CHAMBER SHOWING A MODEL SET UP FOR PRESSURE DISTRIBUTION TESTS ON THE TAIL PLANE

three curved glass windows set flush with the inner surface of the tunnel, two in the floor of the tunnel and one in the top. Besides these inspection windows there are also four illuminating windows with electric bulbs, providing a powerful light for photographic purposes. A general view of the lower story of the experimental chamber is shown in Fig. 3, with one of the curved tunnel doors open, indicating the ease with which the model may be reached for adjustment.

POWERPLANT

The driving motor consists of a 200-hp. direct-current, adjustable-speed motor, with a speed range of from 1 to 1000 r.p.m. At present power is supplied to this motor at 250 volts from a dynamo driven by a Liberty engine in an adjacent building, but as this powerplant is expensive and inconvenient it is hoped that a more suitable source of supply will soon be available. The propeller is direct connected to the motor by a 3-in. shaft supported on a steel framework and mounted in three ball bearings, while the propeller itself is 10 ft. in diameter and has four blades. As this propeller was designed to be driven by a Liberty engine at 1400 r.p.m. it does not at present absorb all the power which the electric motor can deliver and a new propeller with a larger number of blades and a higher pitch is soon to be used which will increase the air speed obtainable in the tunnel to a considerable extent. The main switchboard is at the entrance of the building, and to obviate the necessity of running heavy wires down to the experimental chamber, the control is by automatic push buttons, one for starting and one for stopping, while a field rheostat is used for speed control above the normal rate of 250 r.p.m. and a series rheostat or potentiometer for speeds below this. The rheostats are placed outside of the experimental chamber to eliminate the heat which would raise the temperature in the small chamber to an uncomfortable degree.

In Fig. 4 is shown a curve of power input to the driving motor plotted against the air speed in the throat of the tunnel. It should be noted that the efficiency of the motor with the very small field excitation which occurs at the higher speeds is exceedingly low and the actual power supplied to the tunnel is much less than that supplied to the motor. An approximate energy factor for the tunnel and propeller of 1.90 is obtained, showing an efficiency considerably higher than that for either the National Physical Laboratory or the straight Eiffel type of tunnel. The reason for the power curve showing a sudden increase at the basic speed is because the potentiometer rheostat is connected in at this speed and this absorbs a constant amount of power which is much more than the motor itself absorbs. In Fig. 4 is also shown a curve of the propeller speed plotted against the air speed, that is, the effective propeller slip; and, as would be expected, the slip is constant for all air speeds.

The steadiness of velocity in this wind tunnel compares favorably with that of other tunnels, the maximum variation of the velocity from the mean at any air speed not being greater than 1 per cent at a given point in the tunnel. No manual operation of the controls is necessary during a test, except at long intervals, to compensate for the changing resistance of the motor due to a temperature rise. It was at first planned to construct a speed regulator similar to the one used at Göttingen, but with the proper adjustment of the governor on the generating set, such satisfactory results were obtained that the regulator was found unnecessary. The maxi-

mum variation of wind direction in the throat as deter-
mined by a recording yawmeter is $\pm$ 0.5 deg., and this
variaiton is of such a high period that it does not appre-
ciably affect the readings of the balance.

BALANCES

The balance mainly used in this wind tunnel is of the
modified National Physical Laboratory type, designed and
constructed at the Committee's laboratory, a cross-section
of which is shown in Fig. 5. The distance from the
center of the model to the pivot point on this balance is
54 in., while the distance from the pivot to the end of
the weighing arm is 27 in., so that the weights are actu-
ally twice as heavy as they are marked. The balance was
designed to measure forces on the model up to 50 lb.,
while the weight of the moving parts was kept down to
46 lb. by the use of aluminum alloys and high-tensile
steel. While the National Physical Laboratory type of
balance is convenient and satisfactory for small tunnels
and low wind speeds, it is felt that an entirely different
type of balance must be designed if it is desired to
measure forces any larger than 30 or 40 lb., as it is
found when the maximum forces are used on this bal-
ance that a great amount of trouble is introduced by
deflection of the various members and especially by the
vibration which is set up when a model is turned to an
angle near its burble point. Another objection to the
National Physical Laboratory balance for large forces
is the heavy weights that must be used; that is, for bal-
ancing a weight of 50 lb. on the model, weights to the
amount of 100 lb. must be lifted on to the arms, which
is very inconvenient when rapid tests are being made.
The principal changes besides weights and dimensions
which have been made in the original National Physical
Laboratory balance are as follows:

(1) A ball-bearing pivot is used in place of the usual
conical pivot as the latter gave considerable fric-
tion under large loads and also gave trouble
through a shifting of its position so that the zero
reading was changed during a run

(2) A weighing arm is used for measuring moments
instead of the former torsion wire, and in this
way lift, drag and pitching moments can be
measured simultaneously

(3) The weighing arms are made of light steel tubing,
and to prevent deflection they are trussed up with
tie-rods, thus greatly diminishing the weight of the
arm, while at the same time increasing its stiffness

(4) A pinion is used for turning the head of the bal-
ance to make small adjustments more accurately
and a prism is used for reflecting the horizontal
graduations in a convenient direction

(5) An improved locking device is used on the lower
balance tube

(6) The lift is measured very satisfactorily and
quickly by a Toledo weightless scale, which allows
direct readings to be made

It was found necessary to use a mercury seal to pre-
vent air from passing around the balance spindle into
the tunnel, even though the doors in the experimental
chamber were closed. This is due to the fact that even
with the tightest possible construction there are a num-
ber of small leaks about the experimental chamber, the
air from which accumulating at the crack around the bal-
ance spindle, produces an air flow large enough to intro-
duce a considerable error into the readings of the bal-
ance. This seal is made of cast iron and allows a maxi-
mum head of mercury of 2 in., the height of the mercury
being at all times observable by a glass tube on the out-
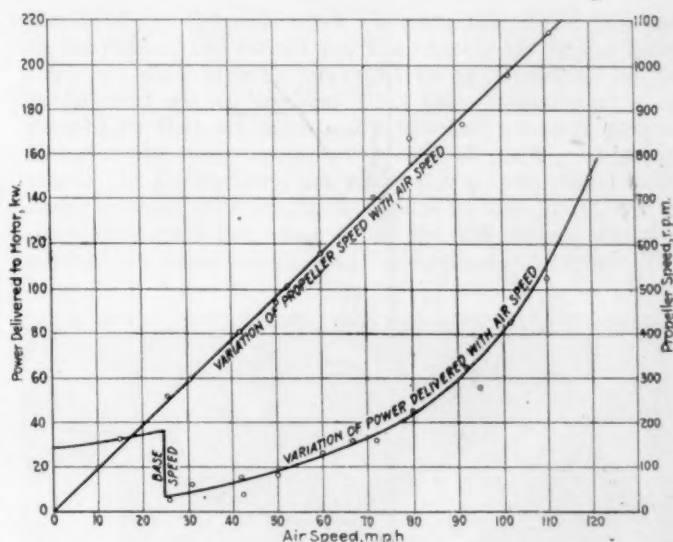side of the seal. Models are usually supported from the

FIG. 4—AERODYNAMIC CHARACTERISTICS OF THE WIND TUNNEL

top of the balance by a tapered steel spindle which is
1 in. in diameter at the base and tapers to 5/16 in. at
the top and this is enclosed up to within 2 in. of the
model with a thin brass fair-water to reduce the spindle
correction to a minimum.[3] As the bending moment in
this spindle is very large at high speed and as there is
considerable trouble with the model vibrating, a method
has been devised by D. L. Bacon for supporting the top
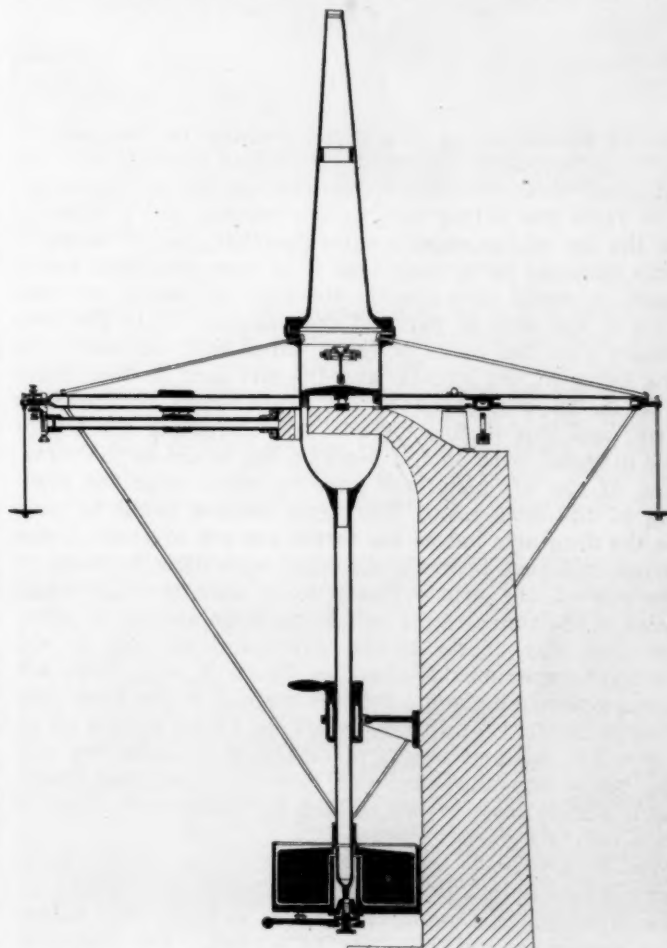of the model rigidly and at the same time reading the

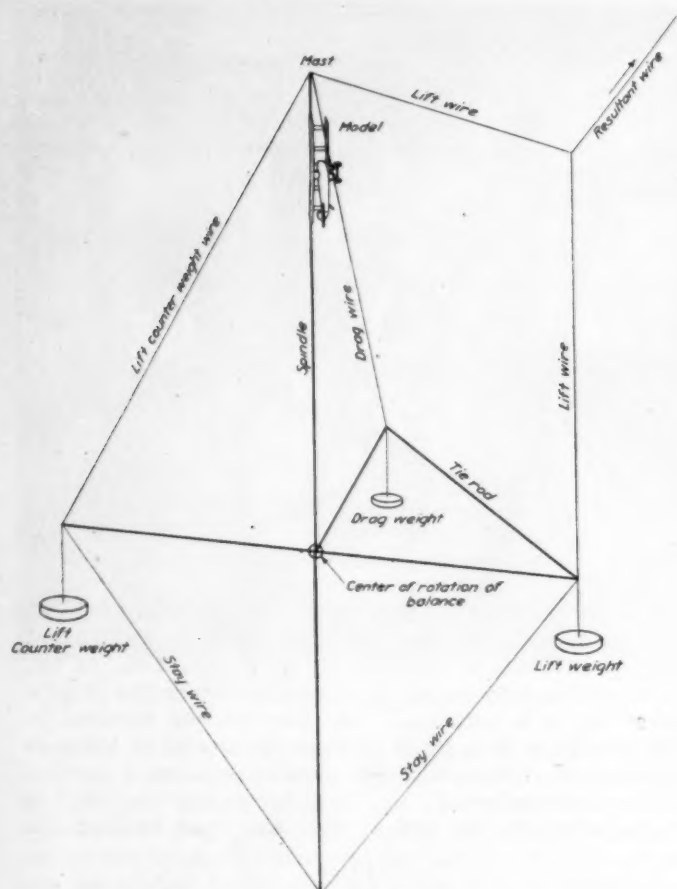FIG. 5—SECTIONAL VIEW OF THE BALANCE USED IN THE TUNNEL

Fig. 6—Method of Supporting Models on the Balance at High Speed

forces with accuracy and great rapidity on the balance.

This method is shown in Fig. 6 and consists of a set of small wires, one extending from the top of the model, one from the lifting arm of the balance and a diagonal to the top of the experimental chamber, the direction of this diagonal being such that if it were projected downward it would pass exactly through the center of rotation of the moving parts of the balance. It is also necessary that the plane of these wires shall be exactly in the plane of the spindle and the lift arm so that there will be no component of lift transferred to the drag arm; and this is done by carefully adjusting the top of the diagonal wire until a force on the model in the direction of the lift plane will have no effect upon the reading of the drag arm. The same method could be used on the drag arm but as the forces are not so great it was found sufficient to run a diagonal wire directly down to the end of the arm. These wires pass through small holes in the tunnel walls which are large enough to allow the free play of the tunnel wires and yet due to the air-tight experimental chamber there is very little air passing through them. By this method it has been possible to test a 1/24 size model of the Curtiss JN-4 up to 100 m.p.h. without excessive vibration or deflection and this speed was the limit only because the model itself, even though made of metal, was not sufficiently rigid to stand a heavier load.

As it is believed that the important development in aeronautics of the future centers about the internal'y braced wing, the Committee's policy is to conduct extensive researches on this type of airfoil. The National Physical Laboratory type of balance is unfortunately un-

suited to tests of this nature, especially where the wings are tapered down to a thin section at the tip, as it is practically impossible to support such a model by a spindle attached to the end of the wing. For this reason it has been necessary to design and construct another type of balance, which supports the wing nearly at its center by wires, as shown in Fig. 7. The lift and drag can be measured on this balance directly, the lift on a Toledo scale and the drag on a small balance connected to the wing by a parallelogram of wires. The center of pressure is determined directly by finding the point about which the wing is in equilibrium when balanced on knife-edges, as shown in Fig. 8. This method is very convenient and accurate and eliminates the large amount of computation which was necessary in finding the center of pressure travel by the usual methods. While this balance does not take the place of the National Physical Laboratory balance for the majority of the tests, still it is a necessity when it is required to support the model by its center and for wings of high aspect ratio where it would be impossible to support them steadily by an end spindle.

SPECIAL APPARATUS

The air speed in the tunnel is originally determined by a pitot tube and the micro-manometer shown in Fig. 9. This manometer can measure a head of water to 0.001 in., which is sufficiently accurate for any work required
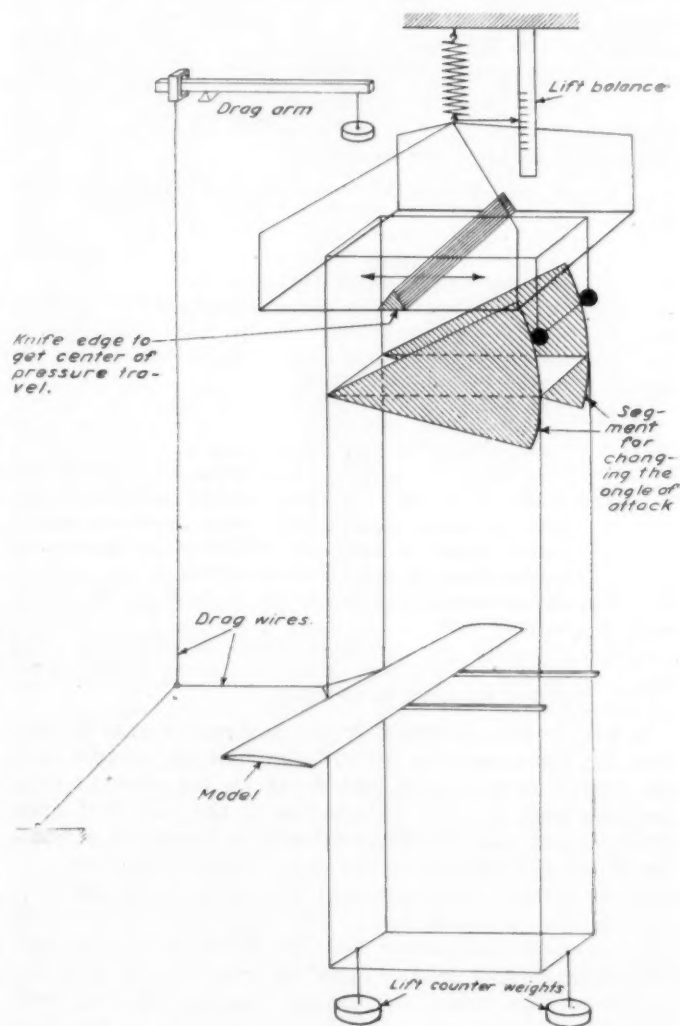

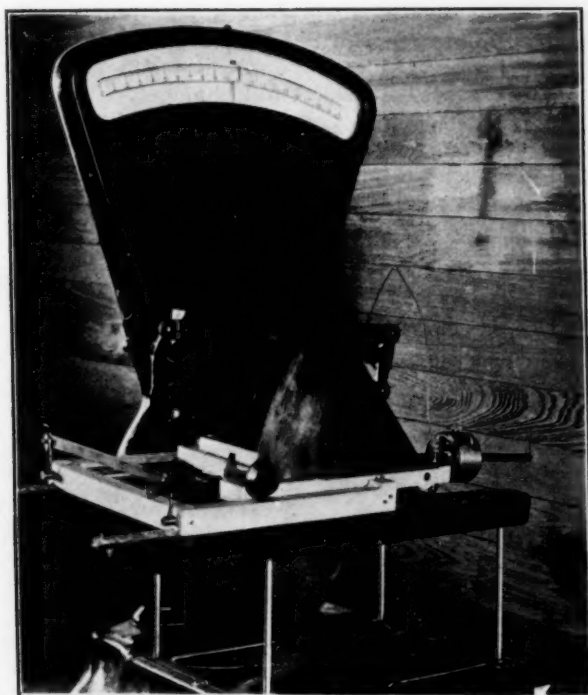Fig. 7—Diagrammatic View of the Wire Balance

FIG. 8—WIRE BALANCE SHOWING CENTER OF PRESSURE KNIFE-
EDGES AND THE SECTOR FOR CHANGING THE ANGLE OF ATTACK

in the wind tunnel, and is very much more convenient than the Chattock gage generally used in wind tunnels, as its sensitivity can be changed by altering the slope of
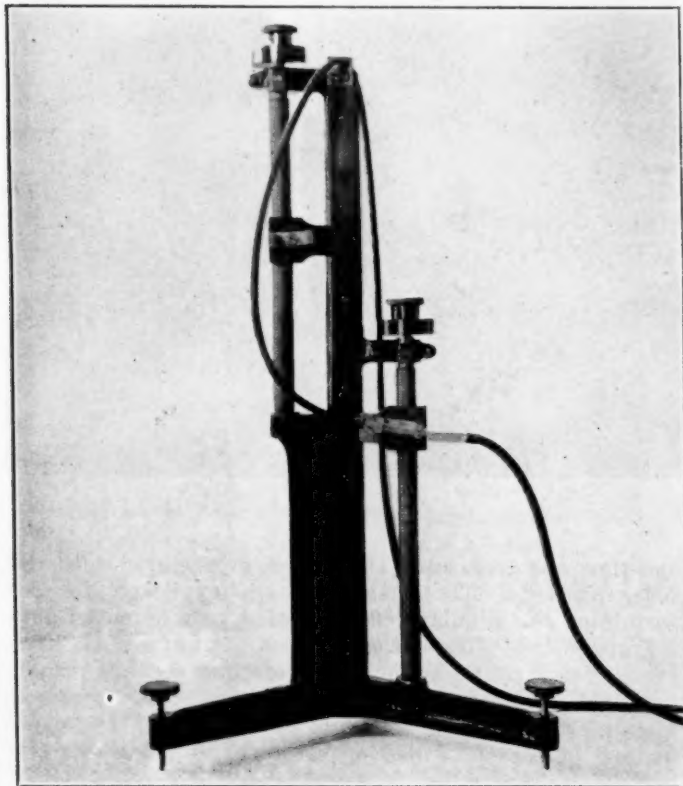

FIG. 9—THE MICRO MANOMETER

termined by the difference between the static pressure in the side of the tunnel and the outside air in the building, this difference in pressure being measured by the manometer shown in Fig. 10. This manometer is arranged so that its sensitivity will be inversely proportional to the head measured so that at the higher speeds where the fluctuations are naturally greater than at the lower speeds, the variations shown by the liquid will be proportionately the same as at the low speed, which is a necessity when running at the highest velocities. This
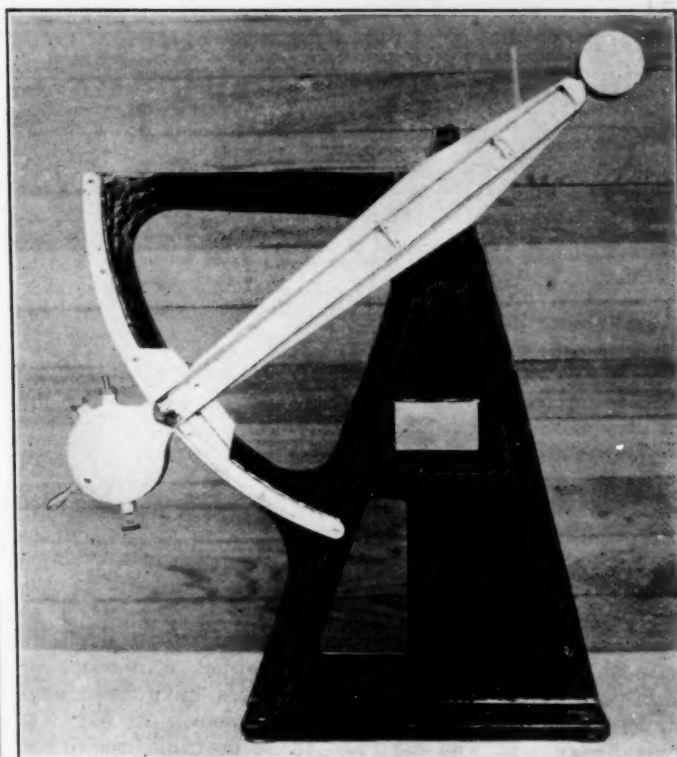

FIG. 10—THE TILTING MANOMETER

gage also obviates the necessity of having a very long inclined tube, which would mean that the meniscus must change its position by several feet, so that the operator would have to stand in different positions for various velocities in the tunnel. This gage is, of course, used as a secondary instrument and is calibrated from the readings of the pitot tube, but actual heads can be easily read on it by measuring the angle of the tube and knowing
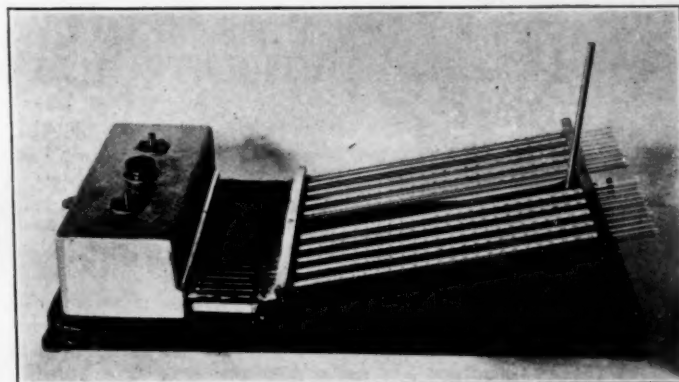
the glass tube, and its range can be extended to a head of 18 in. without difficulty.

For usual running, the air speed in the tunnel is de-
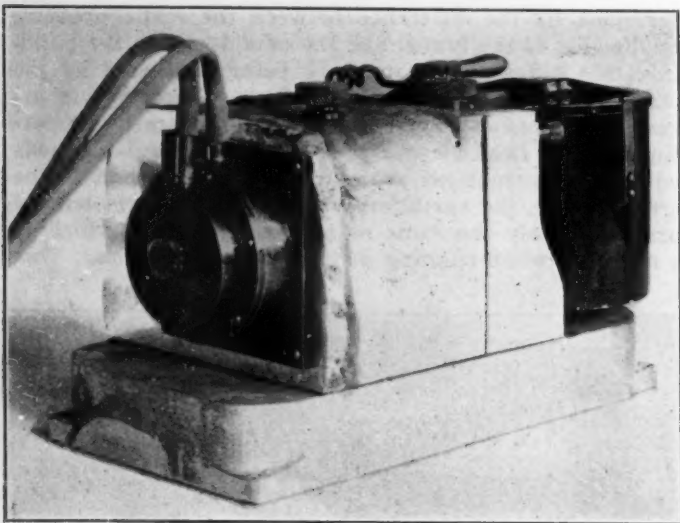

FIG 11—THE MULTIPLE MANOMETER

FIG. 12—THE RECORDING AIR SPEED METER

the distance from the center of the reservoir to the meniscus of the liquid.

A multiple manometer is used to a large extent in determining the distribution of pressure over models, and one containing 20 tubes is shown in Fig. 11. The two outside tubes are connected directly to the top of the reservoir so that they will read the height of the liquid at all times, while the other 18 tubes are connected to the pressure holes on the model. The height of the liquid can be adjusted by raising or lowering the reservoir, while the sensitivity can be changed by varying the inclination of the glass tubes.

For the study of fluctuations in velocity and direction in both the model and full-sized tunnel, a number of high-period recording air-speed meters have been constructed, the most recent one being shown in Fig. 12. This instrument was designed to be portable, requiring only a small battery for the light and the motor, and the film is carried in light-tight drums which are used like plate holders. The sensitivity and position of the zero of this gage can be changed easily, making it available for a large number of uses, while its natural period is so high and the friction is so small that it can easily record the highest period fluctuations that will occur in any wind-tunnel work.

Because of the inconvenience and inaccuracy of the old method of aligning wings by attaching a batten to them and then aligning this batten with a parallel line on the floor of the tunnel, a new method is used consisting essentially of a projector which throws a parallel
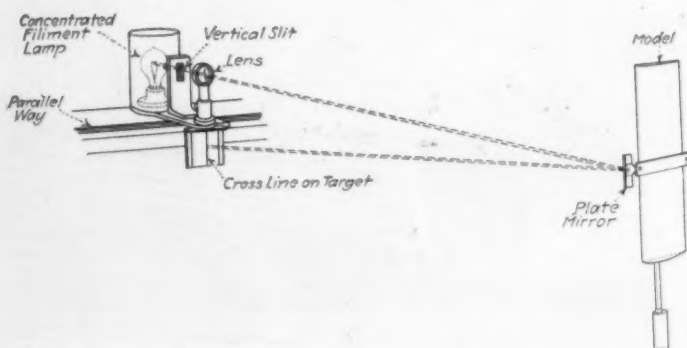

FIG. 13—METHOD OF ALIGNING THE WIRES

beam of light upon a small plane mirror temporarily attached parallel to the chord of the wing, and this beam of light is reflected back to the cross line of a white target on the wall of the experimental chamber, Fig. 13. To align the model all the operator has to do is to turn the head of the balance until the light spot falls on this cross line, which he can see from any part of the experimental chamber, so that one man can line up a wing to within 0.02 deg. in a few seconds, thus greatly reducing
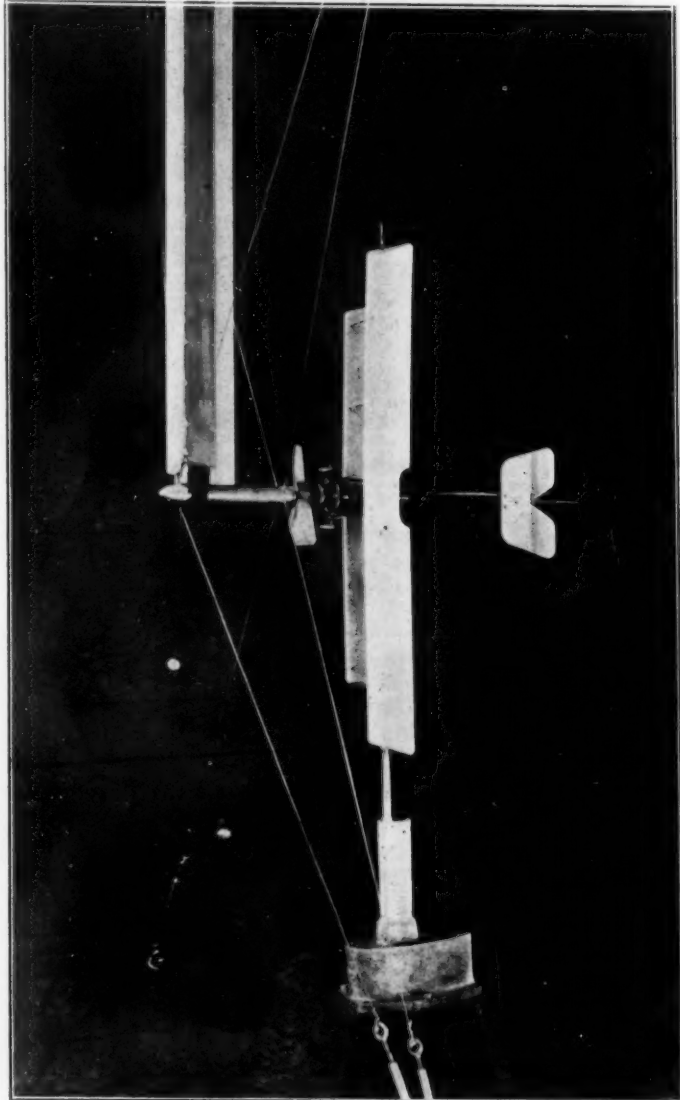

FIG. 14—METHOD OF DETERMINING THE SLIP STREAM EFFECT

the time and increasing the accuracy compared with the older methods. This method is also applicable for determining the angular deflection of a wing or model during actual test. The optical method of aligning has been in use for a considerable length of time and has proved very satisfactory, entirely eliminating those errors in alignment which are bound to creep in with the older method, due to unskilled operators or curvature in the batten.

One of the chief causes of dissimilarity between a model test and a free-flight test is the lack of a slipstream in the model, and to produce this effect in the wind tunnel a small propeller is driven before the model by a belt from a high-speed electric motor above the tun-
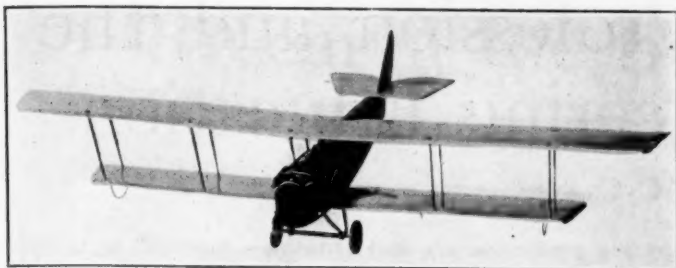
FIG. 15—A WIND TUNNEL MODEL OF AN AIRPLANE

nel, the propeller being supported by steel wires from the walls of the tunnel as shown in Fig. 14. The wires, the belt and the propeller mounting undoubtedly cause a somewhat different air flow from that occurring in full flight, but this interference is probably very small and at least gives us a much closer approximation of actual conditions than has been obtained before. While it has not been possible as yet to drive a model propeller at a proportional speed to the full-size propeller, it has been possible by using a model with a pitch slightly larger than the full-scale propeller to get a slipstream of the same characteristics as the slipstream in the full-sized machine, which should give identical results as far as the interference of the model is concerned. Work is being carried out on the design of a very small high-pressure turbine to drive the propeller at a higher speed and so that a smaller mounting can be used through reducing the interference.

MODELS

While the models tested in the wind tunnel are, strictly speaking, not a part of the equipment, still those models of such standard form that they are used repeatedly in tests can be considered as such. The Committee has constructed two models of the JN4-H airplane, one of them being the 1/24 scale model illustrated in Fig. 15, which is constructed with the greatest accuracy to reproduce all parts that might affect the air flow, that is, the engine, radiator and wind shields, the only omission being the wires and fittings which can be more accurately calculated than tested. The other model of the same machine has been constructed to 1/15 size for pressure distribution tests on the tail surfaces.

All of the medium or thick wings that are tested in the tunnel are constructed of maple, as this material can be worked with proper precautions to within an error of 0.002 in. The wings are cut upon a special machine

[4]See National Advisory Committee for Aeronautics Report No. 54.

shown in Fig. 16, which not only will cut the usual constant-section type, but will also cut wings tapering in plan form and thickness, as, for example, a wing with a depth-to-chord ratio falling off toward the tip as a parabolic function, and at the same time with an elliptical plan form. A much heavier and more precise machine of the same type has been designed for cutting and grinding aluminum or steel wings. Without a machine of this type the Committee's extensive program on thick tapered wings would be impossible because of the great expense of making the models by hand.

The wind-tunnel work of the National Advisory Committee at Langley Field, in contrast to the work of most of the tunnels in this country, is entirely research on the fundamental problems of aeronautics, such as the systematic design of airfoils, the scale effect on models
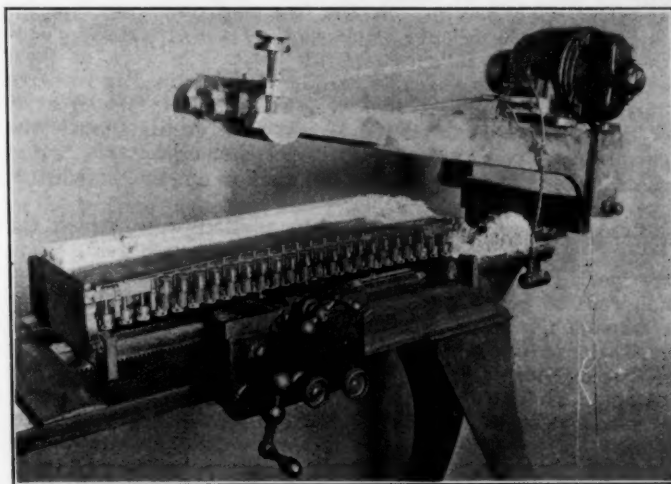

FIG. 16—A SPECIAL MACHINE FOR CUTTING AIRFOILS

and the relation of the stability on models to that in free flight. Fortunately, it is possible to carry this work on most efficiently because of the close cooperation that can be had with the free flight investigations which are being conducted by the Committee at the same time. It is, however, realized that with only one wind tunnel, the various model investigations cannot be carried on simultaneously, and so the work cannot be conducted as rapidly as desired, but it is expected that a second and larger tunnel will be constructed by the Committee in the near future, which will greatly extend the range and amount of investigation possible.

"RICH" MIXTURE FOR STARTING

AN engine does not require a richer mixture for starting up than for slow running, but it does require more gasoline, which is not at all the same thing. For, especially with modern fuels, the constituents that will volatilize at ordinary temperatures are low in quantity and, therefore, only a small proportion of the fuel actually used goes to form the mixture. The rest, under the conditions of low velocity and consequently low atomization then obtaining in the induction system, simply falls out of suspension and becomes deposited. It usually lies in little pools until the throttle is more widely open, when the engine perforce drinks more than is good for it, and chokes and gasps.

Much the same unfortunate set of circumstances occurs with the engine "idling" when cold, that is, very much more gasoline is required for slow running with a cold engine than when the engine is hot. Many people boast that their engine starts and gets away well from cold, and requires no warming up. So it does, at a price. It is not possible, with the present type of slow-running devices, to have economical slow running when hot with the same setting that gives an easy start and idling when cold, and therefore a compromise setting is almost universal in which starting is somewhat difficult, and slow running when the engine has warmed up is extravagant.—*The Car*.

Engineering as a Profession and the Value of an Engineering Education [1]

By Henry M. Crane [2]

THE profession of engineering in some of its branches is one of the oldest recorded in history. This statement which is a rather sweeping one requires some explanation. Engineering can well be divided into two general classes based on certain broad principles rather than into the many divisions commonly used in which the classification is on a purely industrial basis. There are two broad divisions of engineering which cover practically all forms of engineering activity. These are research engineering and constructive or creative engineering. In the former division are included the work of the scientist, the work of the investigator and the work of the inventor; in the latter the work of those whose task it is to assemble the knowledge gained in research during all time and to use such knowledge in the creation of things of value to all the people, such as the simple telephone receiver or the complicated telephone plant of a great city, or in planning for the production of the articles in question.

Research engineering is the foundation upon which the great fabric of constructive engineering must rest; it is the work of the research engineer that was recorded many hundreds of years ago. On the other hand, constructive or creative engineering has grown to its present clearly defined position during the last 100 years. Its development has followed closely the lines of industrial evolution for reasons that are plain. In the earliest days industry was purely personal, as in the making of stone implements or of armor. It was entirely natural that the maker should also design his product. Later on such activities as the building of ships required a community of effort which had appeared from time to time theretofore in the construction of buildings or bridges. In almost every case, however, the director of the work was likewise the one who determined its form.

THE DEVELOPMENT OF INDUSTRY

Until about 100 years ago industry was still relatively in an undeveloped condition, largely on account of the absence of any great prime-mover. It is true that wind and water-power were both used in a small way in various operations, but the coming of the steam engine was needed to start the growth that has resulted in the highly organized industrial world of today. The steam engine by itself could meet only in a limited way the requirements of a great industrial expansion. Coupled with the necessary steam boiler it could not be operated economically except in units of moderate size, owing to the lack of suitable means for distributing the power produced. Electric transmission finally solved this problem not only for the steam engine but for the immense available waterpower previously going almost entirely to waste. The discovery of petroleum and the subsequent development of the internal-combustion engine capable of being operated by anyone of average intelligence and of furnishing power economically in units of the smallest size broadened still further the field of industrial possibilities.

The effect of industrial growth and concentration was an increasing specialization not only in the duties of the directing minds. Under this pressure there came finally an almost complete separation between the work of planning for and the work of directing the production. The work of planning for production, either in designing the article to be produced or in laying out the method of production, has now become the province of the constructive or creative engineer. In the smaller shops the duties of planning for and of directing production are still sometimes combined with those of actual production or operation, but such cases represent a minor proportion of the total. The reason for this condition is fairly obvious; the work of designing or planning requires special training, a broad understanding of the results of world-wide and age-long research in the field to be covered and a constant study of current research. This knowledge cannot be obtained and properly assimilated except under conditions permitting almost undivided attention to the subject in hand and excluding the necessity of giving attention to the multifarious questions arising in the executive management of production or operation.

It is certainly easy to recognize the effect that this development has had on the opportunities for the trained engineer. One hundred years ago a few laboratories or an occasional observatory presented themselves as possible places of employment. Today there is not a single industry that does not make use of the services of the engineer in some way. Even the farmer is finally succumbing to the mechanical operation of the farm. In most industries the engineer has to do not only with the original design of apparatus but also with the methods of production and subsequently with the operation in service.

THE ENGINEER'S PLACE IN INDUSTRY

Furthermore, the engineer is only beginning to come into his own. Originally he was more or less of an assistant to the operating head and was looked down upon accordingly. He was considered to be impractical and not to be depended upon in the daily routine. This was perhaps more or less natural in view of the lack of understanding regarding the two very distinct engineering functions described at the beginning of this paper. In the early days almost the only men called engineers were those having research training and the research point of view. It is not surprising that these men were not successful in carrying any great responsibility in creative engineering work. Engineering ability of the creative kind is nothing but trained common-sense coupled with a certain fund of ready knowledge and the more important understanding of where to go to get any particular information required at any given time. That men having this ability are capable of successfully carrying out most important tasks has been amply demonstrated in recent years.

In any industry of the manufacturing type there are three main divisions outside of the general executive and financial supervision; these are engineering, production and selling. These functions must all be carried out with equal ability for the greatest possible general success of the whole undertaking. In many cases the engineering has been given the least weight of the three. While this has often been caused by some weakness in the engineering personnel, it has at other times been the result of some of the engineering functions having been taken over by one or both of the other divisions, with a consequent weakening of the responsibility of the engineering division and a very natural loss in efficiency.

The assumption sometimes made by the production department that the engineer cannot be expected to design with ease of production in mind is an invitation to the engineering department to disregard this very important feature of design entirely. Here is demonstrated one of the worst faults of the modern industrial system when organization and specialization are carried to extremes. It is only when the engineer in designing any piece of apparatus keeps con-

Research the Bond Between the University and Industry

By A. E. White[1]   DETROIT SECTION PAPER

RESEARCH has been accepted and accredited as a function of our schools and colleges since their very establishment. Even in the days when Latin, Greek, philosophy and theology were the main subjects in the curriculum, it was duly recognized that research in these fields into nooks and crannies still unknown was a fundamental and necessary function for the instructor. Thus, research is no new and untried thing; that which is new is the modern concept of it. The present concept is that in our universities and colleges greater attention should be directed to those phases of research which will mean greater employment and greater prosperity of the people. There are those who feel that such a concept is not in keeping with the best traditions of our schools. They feel that our research, whether in the philosophical or natural sciences, should be abstract or intangible. They feel that the possible sordid effect of money may cause attempts to use research for the selfish benefit of a few. They hold themselves aloof from matters of an industrial character. They realize that their training, their very life-work, has necessarily kept them out of contact with industry and its needs. In their ignorance they are willing to view research in the same light as it was viewed by our forefathers. They are willing to profit by our material advances but unwilling that our universities should do their share in these advances.

To whom do we owe the developments in steam, in electric transportation, the electric light, modern sanitary equipment, the automobile and the numerous other things which make life easier and more pleasant? Would we replace the modern Pullman or the automobile with the leather-sprung coach; would we return to the oaken bucket in preference to the modern bathroom fixtures, or to candles instead of electric lights? It is true that college men have had their share in these developments; the distinction is that this has not been as graduates doing such work in close contact with the university, but as men divorced from the University in large measure, if not completely. It is true that to Charles P. Brush we owe much of the development of electric lighting, and that to Howard E. Coffin and others we owe the modern automobile; both men are alumni of the University of Michigan, but who associates this University with the development of electric lighting and automobiles? I have no quarrel with those who believe that a university should confine itself closely to abstract research. I believe we should encourage work of that type in every possible way. Through it we widen our knowledge, we add to our culture and, in the field of natural science, we work toward laws that are at the foundation of science. I trust that as departments of engineering research develop in universities they will have funds available for work of this type and can carry on such research work as they desire in as great magnitude as the work warrants.

HESITATION TO ENCOURAGE RESEARCH

The mistake that has been made in the past is that undue reticence has been displayed by those in authority at our institutions of learning in encouraging industrial and engineering research. This reticence is possibly a relic of the opposition that engineering education has encountered since the days of its inception. It was only after overcoming much opposition that Rensselaer Polytechnic Institute was established in 1837. It was felt for a long time by many of the leading educators of that period that the training at the school was too practical and not in keeping with the traditions of higher education. Yet today we have no educators of moment who would make such a charge against our modern engineering schools and colleges. Have not many of us as educators gone only half way? In taking a leading part in engineering education but not in engineering research, have we not fulfilled only half our mission? Should we neglect engineering research merely because it comes close to the material concerns of mankind which have great possibilities for adding to our efficiency and comfort? In an attempt to meet the old-time classical viewpoint on research, have we not neglected the modern engineering viewpoint? The neglect is readily explained. It came about because of the very rapid increase in attendance at our engineering schools and colleges; the various members of our faculties had little time or strength to devote to problems other than those of teaching. The money available was consumed in the procurement of buildings and apparatus for instructional purposes.

To illustrate present-day conditions I will state some facts concerning the University of Michigan. There was available for the college year 1920-21 for new equipment the sum of $20,000. Is it realized that this sum must be distributed among the departments of civil, mechanical, electrical, chemical, marine and aeronautical engineering, and architecture? Is it realized that in chemical engineering we attempt to be conversant with inorganic technology, including work in salts and sugars and involving evaporation in all of its various ramifications; with organic technology, including work in dyes, oils and engine fuels; with metallurgy, including iron and steel, copper, brass and bronze; and with fuels, including gas manufacture and coking practice? Do those who have been given opportunities to spend or to authorize the expenditure of sums ranging from a few thousand to hundreds of thousands of dollars for the purpose of solving a given problem imagine that much work of real value can be produced under such limitations? This statement involves no charge against university authorities relative to an improper assignment of funds, because the engineering college is given its pro rata sum; but it does

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imply one of two things. Either we have looked at matters from an utterly inadequate angle, or those who are in the industries have spent money on research like drunken sailors. I believe both conditions exist. It will be to the advantage of industry from all angles if the universities and the research work in our various industrial centers can be brought into closer contact.

This very limitation of funds has seriously hampered the mission of many of our teachers. They attack problems uncomplainingly with equipment that seriously handicaps rapidity of solution. Those who are in the industries would no more think of undertaking tests with inadequate equipment and facilities than they would think of turning Lake Erie salt by pumping into the lake the brine from our salt wells. Yet our teachers carry on their work as best they can, under most extraordinary handicaps. Is it any wonder that results are obtained only slowly? Nevertheless our universities are our most consistent and continuous producers of research. Beyond question, the magnitude of research at industrial plants has far outstripped that at our schools. Where universities spend a thousand dollars, industry spends a hundred thousand. Where industry has every facility of equipment and chemists, draftsmen, engineers, clerks and stenographers, university professors are compelled to do everything themselves. Where a university must take down and replace apparatus because of lack of space, industry builds a special laboratory if necessary. Proper facilities for research at our universities must be provided, if the grade of men necessary for the proper conduct of industrial laboratories is to be forthcoming. It is believed that this handwriting on the wall has been seen and that a day will break shortly when the universities and the industries will be closely allied with respect to research.

Universities are not totally to blame for the present lack of cooperation. There has been and still is a belief in some lines of manufacturing that secret research will develop products of great value. Research that is cooperative with respect to industries of an allied type and with respect to close contact with institutions of learning is the development of the day. Cooperation in this manner means a free interchange of information. It means freeing industry from the fetters of belief in the power of patents and in the value of secret processes. These two bogies have been most powerful agents in preventing rational cooperation. Business achievement is more a matter of business administration and economics than of patents. Can one of our automobile companies attribute its success to patents or are any furniture factories, stove foundries or iron, steel, brass and copper plants dependent for their success upon patents? To one company that attributes its prosperity to patents there are hundreds that cannot make such a claim. Should companies refuse to cooperate with one another and with a university merely because this may entail a surrender of patent possibilities and the control on matters of publicity? Would not the saving resulting from such cooperation offset in practically every case the benefits obtained through secrecy? Even if matters of industrial success depend upon secrecy, including patent privileges and deferred publication, is it expedient, proper or wise that a State institution should be a party to such a course? Should a university lay itself open to possible charges of serving private interests? It would be entirely proper to issue patents in the name of the public, so that the unscrupulous would be prevented from collecting blackmail or deriving improper benefit from something that had been worked out for the benefit of the public.

The Situation in Michigan

Before proceeding to a statement of the proposed work of the department of engineering research of the University of Michigan, let us picture to ourselves the industrial situation in the State. In 1899 Michigan was the ninth State with reference to the value of its manufactured products. In 1904 it had crept to eighth place and in 1914 it occupied the seventh place. The census figures for 1919 are not yet available, but it is safe to say that Michigan has not slipped backward and in all probability is in fifth place, being led by only New York, Pennsylvania, Illinois and Ohio. Detroit has had a still more remarkable growth, rising from sixteenth place among the cities of the land in 1899, to fourth place in 1919. Unfortunately, no detailed figures are available for conditions since 1914. Figures for 1914 are given merely to enable one to draw a mental picture of the type of industries in Michigan, not with any idea of giving a view of the numerical scope of these industries. In 1914 there were six industries in which Michigan took first rank: automobiles, druggists' preparations, refrigerators, wooden goods not elsewhere specified, showcases and airplanes. There were five industries in which Michigan had second rank: furniture, stoves, salt, wood distillation and wall plaster. There were nine industries in which it stood third, seven in which it stood fourth and ten in which it stood fifth. Based upon the value of the product, the automobile industry for 1914 was credited with $398,289,022. By 1919 this had grown to an estimated yearly value of $1,393,000,000. Detroit's quota of this amount is believed to be about 63 per cent. Foundry and machine-shop products, lumber and timber products and furniture, with a value in 1914 of something over $30,000,000 individually, will doubtless show a collective value for 1919 of over $350,000,000. Four other industries, flour and grist mills, tanned, curried and finished leather, paper and wood pulp, and slaughtering and meat packing, produced goods individually to a value of over $20,000,000 in 1914. There were 11 industries with a value of product in 1914 of over $10,000,000 individually: lumber and planing-mill products not included in planing mills connected with sawmills; brass, bronze and copper products; food preparations not elsewhere specified; malt liquors; chemicals; butter; steam, gas and water engines; printing, publishing, newspapers and periodicals; tobacco, cigars and cigarettes; druggists' preparations and illuminating and heating gas. There were 11 industries with a value of product of over $5,000,000 each, 27 with a value of over $2,000,000, 21 with a value of over $1,000,000, 18 with a value of over $500,000 and 24 with a value of over $250,000. The total value of Michigan's manufactured products in 1914 is given as $1,086,000,000. The estimated value for 1920 is close to $3,000,000,000.

During the war it was estimated that 2½ per cent of the value of the finished product was chargeable as the cost of inspection. Should we accept this percentage figure for inspection work and add to it one of similar amount for research, we would have a sum total of $150,000,000 based on a $3,000,000,000 valuation of the manufactured products for 1920, of which $75,000,000 would be for inspection and $75,000,000 for research. If these figures seem too high, go back to your industrial plant and learn the real facts regarding inspection costs; include not only the labor of inspection but the labor lost on work

which proved to be defective before the final assembly; include lost materials, lost supplies such as fuel and lost use of equipment. If $75,000,000 looks like a big sum for research, let us realize that we are taking a State-wide view of the situation. There are men here tonight from companies that have not hesitated to spend $500,000 a year on research. It would take only 150 such companies to make $75,000,000 and when we realize that the number of good-sized industrial organizations in this State runs up into the thousands this sum when distributed shrinks into insignificance.

With this picture before us it is not hard to realize what should be the position of the department of engineering research in its relation to the industries. It should become the research center for the industries. Each main group of industries should band together and problems that are common to all should be worked out in a common center. The University places its facilities at your disposal. To be sure they will be far from adequate when industries fully awaken to what has been placed at their disposal; but there is a basis and beyond that increased facilities imply nothing but buildings and equipment. If these must be procured, it is much cheaper to procure them jointly than separately.

Do you say that we have no problems? I expect that statement from sections which are dying from dry-rot, but not from a State which has shown itself to be as vigorous and progressive as Michigan. The minute we cease to have problems we cease to be alive; may such a day never come. Do you say that we have no problems of a joint character? There again I say that those industries of a similar type that cannot ally themselves with one another to the extent of finding problems of a joint character are not truly representative. They are not the type we desire in this State. They either lack that spirit of cooperation so essential to present-day progress or have become decadent and will not long withstand the continual battering of modern business. Do you say that we are not sure whether we will get results, since we have little choice in the selection of the men who will do the work or the methods of attack that will be pursued in an attempt to solve the problem? I answer that the University will be only too glad to cooperate to find the right man or men for the given problem or problems. Men who will be assigned to problems will be chosen on the basis of fitness, irrespective of whether they are now connected with the University. As a matter of fact, there is not now a man on the faculty who is not carrying a full schedule. This means that the men who shall handle these problems must come from the outside or, if they are chosen from within, we must find men to take the present teaching positions.

Some concern has been expressed that the department of engineering research would develop into a testing bureau. No fear need be entertained on that score unless the industries themselves demand such a laboratory and will procure facilities so that such a laboratory can function. At present, no funds are available for the maintenance of a staff necessary for such a department and there is no building for housing such a laboratory. As a rule, most companies have a laboratory of their own for such work and those which have not can send their routine work to laboratories established for just such a purpose, they being in a position to render the service at a much lower cost than it could be rendered at the University under present conditions.

It is believed that the department of engineering research at the University of Michigan can be of distinct service and value to the industries of the State through the channels of centralized research. It is recommended that the industries of the State having interests closely allied join together and that there be formed in each group a research committee to confer with the director of the department of engineering research on matters relating to problems and policies. Included in this discussion there should come up matters relating to costs and details regarding how the problem or problems are to be approached, with respect to who is to take charge, and other things of a pertinent character. The committee should then report its findings to the interests represented, unless otherwise empowered, and procure from them authorization to proceed with the work. In the case of an individual industry, the same general procedure should be followed.

The University has already pointed out to the industries that, although it is desirous of doing everything in its power to be of service, it cannot assume the cost of the investigation and researches beyond a very nominal figure. The facilities of the University library are at the disposal of the industries. This library is among the largest in the country and is especially strong in technical books and periodicals. No research on a given subject should be undertaken prior to a thorough study of the literature on that subject. Often such a search saves thousands of dollars. On Feb. 1, 1921, the industries of the State were advised of this service, but the resources of the library in this respect have not yet been scratched. The industries of the State cannot afford to make as little use of libraries in the future as they have made in the past. Requests for service can be made to the librarian or the director of the department of engineering research. This service includes the loan of books and periodicals and, at a nominal charge, abstracts, bibliographical lists and translations. The service further includes the use of buildings and parts of buildings when not in demand for instruction purposes. At present, because of the large enrollment, there is no space that can be set aside permanently for this work. For instance, one of the department heads of the University has but one-half an office; if given the same facilities accorded the members of the faculty at Columbia University and the Massachusetts Institute of Technology, he would have two private laboratories and a private office. Further, the equipment and apparatus, when not employed for instructional purpose, are placed at the disposal of the industries at fees sufficient to cover the cost of repairs, renewals and replacement.

Little thought is required to appreciate how necessary is the passage of the budget now before the State legislature if the University is to serve the industries to advantage. The passage of this budget in its entirety is essential, for there is not a single item that can be cut without seriously hampering the work of the University. We are engineers and are interested primarily in the engineering requests, yet the other items are of equal importance. In this budget $1,500,000 is requested for an engineering laboratory. It is vitally necessary that this sum be granted since it will provide increased space for the college of engineering and for the department of engineering research. Considering that today the University has no greatly augmented facilities for engineering training and research over what it had in 1910, that the student body in this college is double what it was then, with good prospect of being trebled by 1930, and that the State has leaped into a commanding position from an industrial standpoint, with the value of its

products increased from $685,109,169 in 1909 to approximately $3,000,000,000 in 1920, is it not time to request increased and improved facilities to train men for the industries and also for research?

The department of engineering research has been established for the purpose of assisting the industries in such proper ways as lie within its powers. It places at the disposal of the industries its library and available laboratory space and equipment. The industry or industries requesting service are to pay labor charges and a nominal fee for administrative expense and the use of equipment and provide special equipment. As a State institution, the University cannot grant special privileges. Therefore work on which patents or privileges with regard to matters of publicity are desired cannot be accepted. It is recommended that problems of a joint character be placed before the department of engineering research for solution. It is believed that by co-operative alliance large sums can be saved each company. The present day is unquestionably one of cooperation, economy and a strong belief in the value of properly conducted research. The department of engineering research is founded upon this basis, trusting that it shall be of great service to the industries of the State, and through them to the State proper, and that it shall be credited with duly laboring for the cause of true science of which research is the chief if not the only servant.

THE DISCUSSION

GEORGE E. GODDARD:—Research certainly is applicable to many different materials that are used in automobile construction. No doubt each company spends much time and money in research work during a year's time. If read by some of the manufacturers themselves, this paper should prove of great assistance to the automotive industry. What way is there in which automotive engineers as a body can help this research work along? It is undoubtedly a worthy cause. Many industries of the State are allied very closely to the automobile industry and many different materials go to make up a motor car, considering all the accessories. Some of the accessory manufacturers have problems regarding materials. All these companies should be able to receive some help through the facilities of such a research department as the University has at the disposal of the industry. Even though these facilities are such that many in the industry would not be likely to have them at their disposal, there is undoubtedly much there that the automotive industry has not availed itself of.

CHAIRMAN HOWARD A. COFFIN:—I have listened with much interest to Professor White's paper. I believe the industries of Detroit do not realize how much of an asset they have in the University of Michigan. We think of the University as an institution that is set apart, a sort of cloistered place where a fellow drops out of life for 4 years and studies. I think that few of us appreciate how vital the University is in the life of the City of Detroit and the State of Michigan. I think few of the industries in Detroit realize how much of real definite value there is to them in the equipment, the personnel equipment particularly, of the University. We should make more use of the University.

PROF. A. E. WHITE:—With regard to the matter of organization, we have had two fundamental committees in the department of engineering research. One is known as the administration committee; it is attempting to work out the policies of the department from the University's viewpoint. The other is a committee that we

call our advisory board; it consists of 100 men, all of whom are leading men of the State, having to do with the mapping out of the policies of the various companies with which they are connected. This committee was selected in such a way that every important part of the State and essential industry should have representation. The department of research was formally established in October, 1920. It is intended that this committee, which has itself appointed an executive committee of 17 members, eight or nine of whom are from Detroit, will convene early in April. That committee of 17 will be requested to appoint subcommittees from each of the essential industries in the State, which will confer with the director with reference to working out close cooperation between the University and the industries.

PROF. W. E. LAY:—As one of the other professors of the University of Michigan, I would like to state that research at the University may be slightly different from what it should be in a factory. The men theoretically should not be in such a hurry to get things out and when given problems ought to feel at the time that they are to follow a problem out in all its details and thresh it out completely. Practically, that is not true with research as it now stands at the University. The men who are attempting any research have too many duties in respect to instruction and other regular work to go as far into details as they would like.

The very atmosphere of the place is different from that of industrial plants. It is suggestive of complete and careful investigation with no element of hurry in it. The University does not require great speed in research. If any research should be done at a university in connection with the automotive industry, it can be conceded that the University of Michigan should do the most of it. Within a radius of 100 to 150 miles of this University are a number of cities which include the greater part of the automotive factories and organizations. No other university is so well situated. The taxes which the manufacturers pay go to keep up this University.

WALTER T. FISHLEIGH:—I agree with everything that has been said on this question, and then I begin to think just exactly what does all that mean in connection with our work. For example, there are many things of a universal nature that we would all like to know. We would all like to get a tire that has all the advantages of an air tire, but that is puncture-proof, is not made out of rubber and would cost about one-fifth as much as present tires and give us 10 times the mileage.

There are 100 or more such problems of universal interest. We work a long time on some problem and get a good idea about it, then this matter of patents arises and we find that the idea is several years late. We need to solve problems of that sort. But practically it is a matter that must be taken up slowly and cooperation is not coming in a minute. I cannot visualize all the details, but I think there are some things that can be worked out. The big problems that we are interested in are very expensive in the main. Different companies are not always interested in the same things at the same time. The problems are not Michigan's problems alone; they pertain to all the States. Many such problems go to the Bureau of Standards at Washington.

We have in our factory today some brake problems. Perhaps some other firms care nothing about brakes. In other particulars our company may be far ahead, on light-weight construction and some other things; so, we are not all interested at the same time. Except for problems that are vital to us today, we are not interested in

research, but I believe there are some fundamental problems where the University can take a big step forward.

PROFESSOR WHITE:—I believe that the problems which will be selected are those which the industry will choose. That is one of the hopeful things with regard to the whole situation; industry is to select the problems on which there shall be cooperation. I think we have the manufacturers interested in this department.

Inadequate funds have necessitated our looking at matters in a small way; and yet I believe that with the cooperation and the power to give the funds that are within the manufacturers' hands, and the ability of automotive engineers to suggest the problems, we have a more hopeful situation than we have had in years. The Regents, through the appointment of a director of research at the University, have provided the necessary machinery for approaching the companies of the industry with reference to cooperation. I want the industries to feel that any investigations that we undertake are their own investigations. I want them to have on the job that man or that corps of men in whom they have confidence to direct the work. Those men may come either from the University or from outside of it. Nothing has been said with regard to whether we could accept work in which persons or firms residing without the State would share the benefit, but I believe the fact that we accept students from without the State constitutes a precedent. I think that if an association requested that research work be done, and a large number of the firms in the association were resident in Michigan, it would be entirely proper to accept the work.

A. I. STEVENS:—The problem of pitting and lumping in a minute way of black baking enamel, which is used so largely in the automobile industry as to be almost of universal interest, has been investigated by the National Paint, Oil and Varnish Association and referred to the various chemical laboratories. It is most discouraging to the enamel or japan manufacturer to fill a 5000 to 10,000-gal. tank, assured that the chemical ingredients, the heat and everything else known are correct so far as possible, and then find that the whole tankful must be scrapped, without being able to tell why. It might be considered a weakness that such a thing could exist, but it is not. All varnish houses have the same experience. Considering the large amount of baking-enamel material used, the trouble is well worth investigating.

MR. GODDARD:—I am acquainted with some of the troubles with enamel. One feature of enamel that has to be considered is the specific gravity. It is a big problem and will become more and more important. The varnish situation is rather interesting to all of us. Varnish workers have been trying to find ways to flow varnish in a way similar to that in which enamel is flowed. I believe some of them have accomplished results which they were forced by circumstances to perfect in a short space of time. I give that as an example because it shows the renewed interest in a subject in which it may be necessary to perfect the practice; something of which there was a fair knowledge in a general way, but which required development within a short time.

M. H. WELLS:—What benefit would the engineer himself derive from research financed by an organization or association? How about the various ideas originating in the mind of the individual engineer? He cannot develop his ideas; he has not the money. His company has not, but his idea would probably be very beneficial to the entire trade. For example, I know of an engineer who has an idea for the prevention of crankcase oil dilution.

He believed he had the right theory, but he simply had to drop it. Could a bureau or a fund be established whereby such individual engineers could present their ideas and have someone carry them out?

PROFESSOR WHITE:—I am hoping that we shall have various committees formed. For instance, we will have an automobile committee. I expect that this committee, in turn, will appoint several committees to handle various phases of the work. I know that the problem would be attacked at the University. If the association felt that the problem was worth while, it would make funds available so that it might be handled. The question of whether it would be handled would be left entirely to the committee appointed by the executives of the companies.

U. G. THOMAS:—It seems to me that this research department will find it difficult to please everybody and really get anywhere. On the tool-life question, after the proper research has been made, how will the manufacturer be told how to utilize that research? In different factories, a drill might be heated in a hand forge, an electric forge or a furnace; the oil that it is dipped in may not be the proper kind to produce the correct temper. Brake-lining has been mentioned, from the production standpoint; I mention tool life from the production standpoint. One car uses a 10-in. brake lining, 2 in. wide and $\frac{1}{4}$ in. thick; another car has a 14-in brake lining, 3 in. wide and $\frac{1}{2}$ in. thick. One car has external and internal brakes; the other has both internal. How are we to arrive at what all of them want? We have many S.A.E. Standards that are being universally used; they are fine and can be universally used. When this research department at the University gets results on the practical points, it will be of vital interest to the manufacturer, regardless of what the individual engineer has to say about it.

PROFESSOR WHITE:—We must draw the line at problems that are of interest to only one individual company. In most cases such problems can be solved at the individual plant. Then we must distinguish between working out a procedure and determining whether that procedure is the right one in an individual plant. To illustrate, I had called to my attention the fact that certain boiler tubes were developing brittleness. Some tests that were made indicated that if those tubes were heated to a light yellow, the brittleness would be removed. The company was advised, but after two attempts the tubes were exactly as brittle as before because they did not heat them hot enough. After a tube was brought up to a light yellow heat under my supervision, it became as tough as a new tube. If we should find out the proper method of heat-treating tool steel and give that method, I will agree that in many plants we would still encounter trouble with tool steels, because of failure to follow the directions. I feel that if manufacturers can be advised to a greater extent than they are now with regard to what should be done, they will be in a better position to control their workmen and will cut down the number of troubles that they have, although we cannot expect that all their troubles will be eliminated.

PROFESSOR LAY:—It appears that all the advantage that might come from this research department would accrue to the manufacturer, but this is not wholly true. If a man has no interest in research and is attempting to teach engineering, he will soon simply die of dry-rot. I believe that those of us who are teaching will reap a very large benefit from this research work. The men whom we teach, and will later go into your organizations, will also reap the benefit.

The Engineer's Place in the Industry

FOLLOWING the regular business session at the Annual Meeting, Jan. 12, 1921, the subject of the Engineer's Place in the Automotive Industry was presented in addresses delivered by H. M. Crane, H. W. Alden, F. E. Moskovics, J. G. Utz and J. G. Vincent. The remarks of the different speakers are printed below substantially as delivered.

ADDRESS OF HENRY M. CRANE

WHEN I began thinking about the origin of engineering as a profession, I was much surprised to realize that it is of extremely recent growth. In making this statement, I draw the line possibly in an arbitrary manner between the experimenter, the investigator in chemistry or physics or allied lines, and the men who take the results of such research work and put them in form for the use of all the people. I think that this is a very reasonable line to draw. A misunderstanding has existed among many of the executives in the automotive industry, especially its financial men, as to the radical difference between scientific experiment and engineering practice, which are of equal importance. This has caused much friction and possibly retarded the progress of the engineer toward a place in the industry equal to that occupied by the selling and production departments.

If we look back only 100 years, we see the shipyard workers fabricating ships designed by the builders; the men who actually produced the ships decided what they would be, in both form and structure. Not 15 years ago, in the coach-building end of our own industry, there were many coach-shops in which the drawings were nothing but the simplest kind of sketches. These were used only as a general outline for the workmen, who took the material and formed it into the desired shapes themselves, guided by their long experience. I believe that such a form of manufacture has many good points; the close connection between the design and the manufacture produced very practical articles. The two departments practically were one. The articles possibly might be criticized because of theoretical considerations, but the men who were successful became successful because what they produced actually operated and gave service.

THE ERA OF SPECIALIZATION

As industry and the individual industries became greater in size, we started on an era of specialization. I imagine that the beginning of the engineering profession was largely in the drafting-room, where the then engineers put down the ideas of the boss as a matter of record, for future reference or to be transmitted to the workmen. The activities of these engineers, who were then engineers in name only, if at all, continually broadened as time went on until in many cases the designing came entirely under their direction. However, in the automotive industry this designing was largely the primary stage of production, because no design was sacred from the hands of the production man. I do not take the attitude that designs should have been sacred from the hands of the production man; I simply am making a statement which we all recognize to be true.

Those who have followed me so far will feel, with me, that the engineer has reached a milestone in his progress, but that he has still a considerable distance to go. The engineer and the shop and the sales department in many of our companies are too widely separated at present; in other words, we have reached the extreme of specialization. In the mind of some men the engineer is not supposed to know about what a salable automobile should be, but should take his directions from the sales department; he is not supposed to know how an automobile can be built in an economical manner, but should take his information from the shop. The shop, likewise, is not supposed to know what constitutes a correctly designed automobile, but is supposed to take its information from the engineers. It is evident to me that a system rigidly conducted on those lines has very little chance in competition with the old system of 100 years ago in which the knowledge was combined in one executive, in the final efficient production of the best article. I do not wish to be understood as saying that we can go back to the conditions of 100 years ago; we cannot. No man living is big enough, mentally, working the hours per day that a human being can work, to combine in himself all of the various forms of knowledge required in the operation of a large plant such as the financial requirements, the human element of handling the workmen and the tremendous factors of that kind which did not exist 100 years ago. On the other hand, I think we can approach the efficiency of the old system if the engineers will grow to the point to which I am sure they can grow, and that they will attain in the not very distant future.

The engineer is expected today to know in general the foundation principles of the vehicle he is designing, the use to which it is to be put, the action of the various parts and the probable strains to be met therein, the general theory of combustion in internal-combustion engines and like matters. I do not see why the man who is mentally capable of understanding and applying those principles is not mentally capable of understanding and applying what to me are the much simpler principles of machine production. The fully equipped engineer should be thoroughly conversant with the principles of cutting metal of all kinds in all forms. These principles are really simple and actually very few in number. In addition, the well-grounded engineer should know the capacity for accuracy of the various production operations. For instance, he should know what a grinding machine that grinds shafts of 1-in. diameter should be able to do, day after day, in thousandths of an inch of tolerance either way from the desired size. He should know the same things regarding the grinding of cast-iron cylinders, the machining of aluminum parts and the cutting of gears. Not only should he know these things but, in preparing his designs, he should use such knowledge at the start.

Some engineers feel that the shop will take care of these things and that the whole burden on them is to have something that will run. That is the fault of specialization. Unless the engineer has the fullest comprehension of the difficulties to be met in the shop and gives as much attention to those questions as he does to the questions of the best form of combustion-chamber and the kind of spark-plugs to be used, we cannot get the efficient operation of our factories that we ought to have. The shop, under those conditions, has to meet the engineer half-way. I have had experience with seven factory managers in the last five years. The difference between the best and the worst of those factory managers was almost

entirely in their point of view. The best one took the viewpoint that he was building an operating engine. He encouraged his foremen and his superintendents to look at it in the same way. The reverse of this condition is when the foremen and the superintendents look at the product solely as so many piece numbers for which they have blueprints and what is to them an entirely arbitrary inspection. My contention is that the shop which educates its personnel to realize that the inspection is not arbitrary, that it is based on certain definite requirements, will go a long way toward obtaining the highest class of results in the cheapest possible manner.

SALABILITY OF THE PRODUCT

I think another branch of the automotive industry comes equally within the province of the engineer; it is the salability of the product. It is much more conceivable to me that the trained engineer is the best judge of what car should be built to meet a given public demand than that the sales department should be the best judge. The engineer knows what can be done and, if he is broad-minded enough and sufficiently observant, he ought to have a very thorough knowledge of why the public demand certain things in cars. I think it is not difficult to obtain such information without actually being an employe in a salesroom or a sales manager. In fact, I think the salesroom frequently produces a rather artificial point of view; it is the point of view of that day. The engineer's job is not to say what is salable today, but what will be salable two years hence when he shall have been able to design the piece of apparatus and the factory shall have had time to build it. That is why I say that the engineer, if his training is proper and if his point of view is correct, ought in general to be a better judge than the sales department of the proper thing to build to meet a given demand.

I am asking a great deal of the engineer. In fact, in many ways he must have a greater fund of correct information at his disposal than any other member of a company. He must know his own part of the work, the results of research in the past and of the research going on from day to day. In connection with production he must know the actual methods in many allied industries; he must know the general methods of drop-forging, the general methods of producing stamped sheet-metal work, and foundry and pattern-making methods. The automobile chassis plus the body includes in its structure almost every form of manufacture that we have today, and the engineer must have a thorough grounding in almost every one of those lines if he is going to do his part of the work successfully. I have outlined already the necessity for his knowledge of shop practice. He must have also a knowledge of merchandising which will lead him to have a correct judgment on what the public will want in the future, and a correct judgment that the article can be produced at the price that the public will be willing to pay for it.

I admit that today we do not live up to my ideals of an engineer, but I believe that, if the engineer will grow along the lines I have indicated, he will demand a much larger place in the industry than he fills today, because he will merit it.

ADDRESS OF H. W. ALDEN

THERE has been no time when the position of the engineer in the trade and particularly in the automotive industry has been any more at the parting of the ways than it is today. We have gone through a wonderful period of engineering development and experimental work; we have experienced an amazing time of commercial development, when almost anything that would run on four wheels would sell; and now, for the next few years and perhaps perpetually, we are faced with the situation of the survival of the fittest.

ENGINEER'S PLACE DEPENDS ON HIMSELF

In trying to outline what will be the position of the engineer in our industry, one of the things that occurred to me is that his position will be just exactly what the engineer makes it. In my work I come into contact with probably 150 different engine manufacturing companies more or less intimately; also with a good many purveyors of material. In some cases there are peculiar conditions to which what I say does not apply because of very unusual circumstances, but I have found it largely true that the standing of the engineering department in any commercial organization is measured very largely by the ability of the engineering department itself. As a concrete instance, if a motor-car company has a wide-awake, live engineering organization, that organization plays a very large part in all the activities of the company. If it is made up of individuals who are not any too strong, then that department does not cut very much figure and takes its instructions from other departments. Just what position the engineer will maintain in the automotive field or in any other field will be measured entirely by his service. Just so far as the engineer serves all branches of his organization and the industry with which he is connected, will he play a part.

We have engineers who have come from two sources. One is the so-called technical graduate; the other is the engineer who has come up through the ranks. I do not presume to make any class distinction between the two. Both those who have had a preliminary technical training in some engineering college as well as those who have carved their own way out and availed themselves of that line of study and development which they have gotten by their own hard work, have gathered together certain information, certain lines of thought and lines of action which it seems to me places a responsibility on them which does not rest on the shoulders of any other department in modern organizations.

Mr. Crane has spoken very forcefully of the necessity that the engineer know all sides of his business. I cannot let the occasion go by without emphasizing that. It is just as much the engineer's job, in my opinion, to know how a piece can be produced, as it is to design that particular piece; in fact, I cannot conceive how he can design a piece of apparatus intelligently unless he does know all the steps of production in that device. He may get something that will work, but he will not get the last word in that device. It is just as much the engineer's business to know where and how that article will be sold, as it is how it will be designed or made; but it is a very striking fact, as one talks with engineers and sees what they are doing, to notice how few engineers really seem to know what will be done with the product after they get it off their shoulders. My sympathy very frequently goes out to the shop man who has to make what the engineer designs, and to the sales department that must sell what the engineer designs.

So far as the individual in an organization is concerned, his value to that organization depends very largely upon the measure of responsibility which he is willing to accept. That is equally true of the engineering and the other departments in any company. All of us

know men, perhaps men connected with our own organizations, who think that their little responsibility starts at a certain point and stops at some other certain point. If they are given a job that starts somewhat earlier and goes somewhat farther, they will shy at it. That kind of an engineer will never get very far and, unless that spirit is eliminated from that individual, he will fade away some day and will wonder why.

Another characteristic of engineers, which is disappointing in many instances, is lack of thoroughness. It frequently is necessary to gather some information from which to draw a conclusion; to build up some device, we will say, to take the place of the device that is being investigated. I venture to assert that there are not five men in a hundred who can go out and make an investigation of the situation and come back with the solution. The man who cannot come back with the solution is not particularly valuable.

Briefly, I believe that the position of the engineer in the automotive industry today is at the turning point, and that he can make it just exactly what he wants to make it. The engineer ought to be the central figure in our organization but, unless the engineering organization in any business serves all branches of the business and merges its own individuality, ignoring questions of who is responsible for this or who is to get the credit for that, we will not progress as we ought to progress. I doubt if there is an engineering society in the world that has such an opportunity to serve its industry as the Society of Automotive Engineers has; but only insofar as we are of service will we succeed in attaining our proper position in that industry and in maintaining it.

ADDRESS OF F. E. MOSKOVICS

THE individual that Mr. Crane described is not an engineer; he is an industrial wonder. When he attains such a position, he becomes the president of his firm. Mr. Crane left out only the financial side. Why he left out that detail I do not know. If the engineer is to be a judge of the commercial side of the demand without consultation with the sales department and can design the methods of production without consultation with the tool-designing and the production departments, why should he not know the small details of finance?

There are two forms of engineering that are not clearly recognized in their exact sense. I refer to those two forms constantly in our own business. There are some contacts that I believe no human being can get. A question just asked me proves this to my mind: "About what proportion of closed bodies are we going to build?" I said that limitations are put on one man, if nothing more than the limitations of geography; as long as San Francisco and Los Angeles persist in being 2000 to 3000 miles from our source of production, I do not see how an engineer can be out there every two or three months.

Two Forms of Engineering

The two forms of engineering that I believe are developing more and more as the keynote of our industry are the following. First, technical engineering, which can be taught in any first-class school. The man who studies the other form I would call an empirical engineer. I do not know but that the empirical is a somewhat more important form than the other. The empirical engineer is the very type that Mr. Crane described. I have found that the very finest machine in the world, founded on the very best technical information, can be designed and that

one or several can be built, driven to San Francisco or any other place on a test trial, brought back and put into production; and then that when a thousand or more are put out there is something wrong. It is that something that I do not believe any one man can eliminate from an automobile without the cooperation of a number of other departments. The secret, to my mind, lies in those operations that can be turned into cooperations. That will bring us to the desired result. I think the czar that Mr. Crane described cannot do it without a most hearty cooperation of all the other branches, and unless he accomplishes it in the form of cooperations. If he is a czar, he might just as well have the name of it and be the president of the organization first as last. I will concede that interpreting the trend of future design is the greatest function of an engineer, but I believe that the engineer must temper his effort and be controlled by intelligent discussion and cooperation. A man cannot sit down and dictate some certain thing the public ought to have without having the ability to interpret that thing intelligently. To interpret it, he must have contact with the public. So long as the public persists in living in various places in different parts of the world, the man who interprets must listen to the salesman and the advertiser.

As to the cooperation of an engineering department with a production department, I cannot see it in any other way than that of actual contact between the two departments. I have for years past heard it said, not only in the last several years but in all the years that I have been connected with the automotive industry, "The design is absolutely right if only the production department would make it according to the drawings." The answer is that they would be right if only the production department could make the drawings commercial. If we can find an engineer that is a tool-maker, a designer, a shop superintendent and a sales executive, I will admit that he ought to be everything that Mr. Crane recommends, but then he could not be called an engineer.

ADDRESS OF J. G. UTZ

IN listening to the remarks of Mr. Moskovics and to the various statements that have been made about cooperation, I am reminded of a remark I heard made some time ago. It is that the difference between failure and success is the difference between dignified acquiescence and cheerful cooperation. I think that engineers are getting more toward the latter field as we go along. The greatest development of the American engineering profession, particularly in the automotive line, has been brought about largely by the Society of Automotive Engineers. Some of us who were in the old mechanical branch of the Association of Licensed Automobile Manufacturers remember, in fact, so many years ago that only a few gray-haired men here and there can remember, that there was a time when the experimental department, the engineering department and most parts of the shop were under lock and key and had guardians at their doors. Going back into the ancient history of that time, I can remember a meeting of the A. L. A. M. at 7 East 42nd Street. Something was asked about the fit of piston-rings. Almost everyone told what he was doing but, in going around the room, they finally called on one member who said he believed he would keep his information to himself and that he did not want others to build as good a car as he himse'f was building. That attitude was prominent in those days, but it has gradually dis-

appeared. Today, when traveling around as I have the good fortune to do now and then, about the first thing an engineer desires is to take a visitor down to his experimental room and show him what he is working on. The visitor sees things which will not become public for several years. The former practice of the profession was rather to keep such things to oneself. The very openness of the methods of engineers today, in regard to showing what they have, is one of the best criterions of the advancement of the American engineer. This practice is growing all the time.

I do not believe the statement that the Society of Automotive Engineers is standardizing the engineer out of a job is entirely true, although one can nearly design a car from the S.A.E. HANDBOOK today. Growth and advancement are evidenced by the fact that engineers are being moved up to positions of greater authority. We have some examples of engineers having arrived at the vice-presidencies and presidencies of their companies.

ADDRESS OF J. G. VINCENT

MR. CRANE and Mr. Alden have given a very good picture of why the engineer must in self-defense be thoroughly proficient. I think that one need go no further than just to realize that there is nothing in connection with the automotive industry that cannot be blamed on the engineer, thus proving that the engineer must be prepared to protect himself at every turn against every other department if he is to make a success. I know of no other department, in manufacturing or in the selling organization, that cannot be checked up with proof as to whether it is efficient. There is no really good way to check up whether an engineering department is efficient until all the processes have been gone over and the business made a success. Anything along the entire line can slip unless the engineer is there to protect himself.

ENGINEER SHOULD COOPERATE

Mr. Moskovics took a different viewpoint from what Mr. Crane and Mr. Alden had in mind. I know that neither of the latter had in mind that this engineer should be a czar or that he should be anything except the finest cooperator in the world. What they did have in mind, however, is that he must know his business, so that the result of this cooperation will be along the right line.

I have had some personal experience in that connection. In one plant where I took charge of the engineering there had not been the proper cooperation between the factory and the engineering department. The engineering department said that the factory did not want to work to drawings, was not interested in building the kind of a vehicle that ought to be built, and that it could not get the factory to work to drawings. On the other hand, the factory said that the engineering department did not know anything about designing and drawings. There you are! We cannot expect cooperation until both parties have a fair idea of the other's job. If the head of the engineering department and his assistants know shop practice and have the right mental attitude, they will not have much difficulty in getting full cooperation from the shop. Most shops, if they are managed properly, really appreciate cooperation.

So far as the sales department is concerned, the engineer will have no trouble there either. He cannot, of course, have full details of information as to all that is going on throughout the entire country. The members of most engineering departments whom I know of are too busy to take extended trips very often, but if the engineer is the right kind of a cooperator and has the proper initiative he will be so closely in touch with the sales department that he will know more about those conditions than they themselves will know. This is because he will know the engineering reasons that underlie the results that the sales department is obtaining, or the results it is not obtaining. I think there is no doubt that the engineer is taking more and more responsibility for the various activities throughout the various plants. As Mr. Moskovics says, he is working then toward becoming an executive. Well, why not? I know many big executives in this country who have worked up from having been engineers. I can think of nothing better than a good engineering training and experience to fit a man for executive work.

THE MOTOR CULTIVATOR

OVER 40 per cent of the total crop area of this country is devoted to the growing of crops planted in rows. These rowed crops represented over 50 per cent of the total crop value in 1919. Corn is the leading crop of the country, both in acreage and value. Hay and wheat are very close for second and third places and cotton is fourth. Thus two of our four leading crops require cultivation and are adapted to the use of the motor cultivator. These rowed crops, all big revenue producers, require more man labor and horsepower-hours per acre than most other crops, and it is therefore important to use the most economical methods possible in their production.

In the States of Iowa, Illinois, Nebraska, Missouri, Kansas, Indiana and Ohio, the percentage of rowed crops to total crop area varies from 46.6 in Iowa to 23.9 in Kansas. This is the region where power farming has had a great development, and in which the motor cultivator should be most rapidly introduced. In such States as Michigan and Wisconsin, where a general type of farming is followed, the percentage of the total crop area in rowed crops is not large. The introduction of the motor cultivator into these States will depend largely upon the extent to which it can be used for other work, and it is possible that in such States the preference may be given to the general-purpose type of machine.

One cannot study the figures showing the relative importance of rowed crops in American agriculture without becoming convinced that the motor cultivator has a great future. There can be no doubt about the possibilities for the general use of this machine. The next question is, what does it offer from the farmer's standpoint. In the first place, it means a saving of time in cultivating rowed crops. With a two-row machine one man can cultivate from 10 to 25 acres in 10 hr. depending upon the condition of the crop. When the plants are small the rate of travel is necessarily slow, but as they become larger the speed can be materially increased.

In addition to the cultivation of rowed crops this machine can be used to pull soil preparation machines, such as the disc and the harrow; drill grain, plant rowed crops, mow hay, cut grain, pull the hay-rake, tedder and loader and operate belt-driven machines that do not require more than 12 hp. This prime-mover is so new that its full possibilities for general work on the farm are not fully realized as yet.

The present situation regarding the motor cultivator can be summed up as follows: (a) there is a big potential market; (b) the machine is practical; (c) relatively few have been sold and (d) in many territories it has scarcely been introduced.—E. A. White in *Farm Implement News*.

THE BASIC INDUSTRY

NEARLY one-third of the people of the United States, or more than 30,000,000, live on farms. Nearly 20,000,000 more live in communities having a population of less than 2500. In other words, nearly one-half of the population of this country is to be found on farms or in the country districts. The farming interest is not comprised entirely, however, of those who actually live on the farms. Something like 40 per cent of our farms are rented and many of the owners live in cities and villages. This means that among the merchants, lawyers, doctors, real estate operators, bankers and insurance men of our cities and especially the cities and villages in agricultural sections, there are owners of farms or men whose business is directly dependent on or connected with farming.

The amount of capital invested in farming is constantly increasing. In 1910 the value of all farm property was approximately $41,000,000,000, or more than the capital of all the manufacturing establishments, railroads, mines and quarries in the United States. The value of farm property in 1919 was estimated at more than $51,000,000,000. From 1860 to 1890 this value increased steadily, but during the decade beginning with 1900 the increase in the value of farm property was greater than the entire accumulation of farm property in all the preceding years of our history.

With the increase in the value of farm property there has come a remarkable growth in the value of the farm output. In 1879 this output was valued at $1,500,000,000. No startling growth above this level took place during the next 18 years, but in the 10 years that followed 1897 the increase was nearly 100 per cent. In the next 8 years it increased only about 50 per cent, but under the impulse of the war the output from 1915 to 1917 increased again by 100 per cent, reaching a total gross value of about $16,000,000,000.

The national income from the farm began to rise about the time the population began to increase more rapidly than the area of improved land under cultivation. While the total volume of farm crops increased only 10 per cent from 1899 to 1909 the population increased more than twice as rapidly, so that with the increased demand for the crops the total value of the crop output increased by 83 per cent. This situation seems likely to continue in view of the steady drift of population toward the cities and towns. While 70 per cent of the population of this country lived on farms and in unincorporated villages in 1880, and 30 per cent lived in cities and incorporated villages in 1910 the city population was 55 per cent of the total. If from the 45 per cent representing the rural population there be subtracted the number of families living in unincorporated villages, it will be found that less than one-third of the population is now living on farms. Therefore, while in 1880 one farm family needed to raise enough food to sustain itself and part of another family, in 1910 one farm family needed to raise enough food to sustain itself and two other families.

EFFECT OF THE WAR

It has been stated that the gross farm income of the country increased more than 100 per cent after the war began. In the three oldest of the Middle Western States, Ohio, Indiana and Illinois, the average gross value of the 13 principal crops per farm in 1917 was $2,288, as compared with $964 on the average for the prewar period of 1911 to 1915, an increase of 137 per cent. It is estimated that farm costs increased 50 per cent during the war.

At this estimate the $964 received in the prewar period had merely covered the cost of production; one-half of this amount or $482 would represent the increase in the cost of production in 1917. Subtracting this from the total increase of $1,324 there is left an increased net profit of $842, an amount only $122 less than the average gross earnings on a prewar basis. Every section of the country showed a marked increase in the value of farm crops. The advance was least in New England, where the increase of 48 per cent was

only about enough to cover the increase in cost. It was highest in the great agricultural belt of the central portion of the United States, showing an increase of 123 per cent in the Central West and South and an increase of 125 per cent in the area between the Mississippi River and the Rocky Mountains.

In 1904 the Department of Agriculture received appropriations of more than $6,000,000. In 1918 the appropriations were $68,000,000. In 1917 the amount appropriated for the support of agricultural colleges was nearly four times what it was in 1904. Agricultural colleges are the backbone of farming progress.

USE OF MACHINERY

The use of motor-driven machinery and vehicles has enabled the farmer to save uncalculated amounts of time, energy and charges for maintenance. The telephone and the electrical plant have given the farmer advantages in production comparable with those derived by other industries.

As these mechanical contrivances have reduced in effect the size of the farm and saved labor they have made possible the extension of the area of cultivation. It takes about the same investment in buildings, the same self-binder, automobile and tractor for a farm of 100 acres as for a farm of 160 acres. The overhead charges are usually greater on a smaller farm. The tendency, therefore, is toward the larger farm. From 1900 to 1910 the number of farms in the classification of 20 to 100 acres tended to decrease and the farms from 100 to 175 acres in size remained about stationary, but farms of larger acreage, from 175 to 1000 acres, where the use of mechanical equipment is more general, showed a marked tendency to increase. There are about 1,150,000 farms of more than 175 acres in this country.

The trend of population toward the city has had a reflexive effect upon those who remain on the farms. They have not only sought to obtain for themselves the things which make living in the city attractive, but they have also assumed a different attitude toward the country. They have become less isolated. They have taken a keener interest in affairs. They have come into closer relations with their fellow men.

THE COUNTY AGENT

One of the most important forces in improving agriculture to-day is the county agent. There are 2920 agricultural counties in the United States. In over three-fourths of the counties a county agent is now employed. In several counties one or more assistant agents are also hired. They take out to the farmer better methods of farming, help him to produce more efficiently and to market his crops more advantageously to earn more money.

In addition to the county agents, some of the large city banks employ county agents who guide the farmers in applying loans to uses that will increase their net profits. In some instances railroads employ county agents. Banks, railroads and city chambers of commerce have actively promoted the county agent movement and have extended financial assistance.

In each of approximately 1700 counties a woman home-demonstration agent is employed to work with the farmers' wives and daughters. Not only are better methods of canning, care of poultry, etc., taught, but better sanitation and more home improvements are installed and more organizations of farm women are promoted. In the near future every agricultural county in the United States will probably have both a county agricultural agent and a home-demonstration agent.

EDUCATIONAL AND HOME IMPROVEMENT

Education on the farm is improving. The one-room country school is slowly passing away. Its place is taken by the consolidated school, with a larger enrollment, better teachers

Economy and Performance Demands

By J. G. Vincent[1]

ECONOMY and performance are diametrically opposed to each other. In other words, the greater the performance demanded, the less the economy is likely to be. Peculiarly enough, when economy is mentioned, the average user thinks only about gasoline economy. On account of the fuel situation, it is very important that we work for greater gasoline economy; but if it were not for that, I think it would not be so important. As a matter of fact, the gasoline bill of the average user having an average car is not the major portion of his expense by any manner of means.

Regarding gasoline economy and supposing that we are considering gasoline economy on a type of car that has what is considered good performance, a car that will go nearly everywhere on high gear, such a car must have an acceleration from 5 to 30 m.p.h. in from 12 to 14 sec. The economy of that car is very largely determined by the engine design, the chassis design and the tires. I will point out the problems as I see them, because I do not know their solution. I wish I did.

Engine Design

The engine design is greatly limited in a certain way; that is, the economy is limited by the demand for performance. We can design an engine in any one of three ways. We can take a small engine, run it at high speed and use a big gear-reduction. We can go to the other extreme and design a large engine, run it at slow speed and use a small gear-reduction. We can design an average-sized engine, with an average gearing. The high-speed engine would probably be geared somewhat above 5 to 1, the average being about 5.25 to 1; the slow-speed engine might be geared about 2.50 to 1 or 3 to 1; and the medium-speed engine about 4 to 1 or somewhat lower. Granting that the engine is of good modern design and well built throughout, I believe there will not be much difference in economy between those three types of engine, provided the design is equally well carried out. I base that statement on the fact that the larger engine is likely to have to have slightly lower compression and to be somewhat less efficient; probably it will have less friction at the speed at which it normally runs.

I think we do not all realize that, whereas with a moderately light car having everything tuned up right we can drive say at 25 m.p.h. and get 20 miles per gal., if we could eliminate all the friction in the chassis and all the power that is required to turn the engine over, we could get 56 miles per gal. I am not in a position to prove this statement, but we have made some very exhaustive tests. I believe we have been attributing too much of the lack of economy in engines to throttle conditions, and that we have not been paying enough attention to the friction, particularly the friction of the engine which requires horsepower to turn it over. In other words, we are burning much more gasoline to turn the engine over than is required to drive an average car 25 m.p.h. This will bear investigation.

As to the chassis, there are many good types of design. It is not my task to discuss design, except to say that the chassis should be of well-balanced design in which friction is cut down to the lowest possible minimum, and that the adjustments should be so easy to make that the driver will not be compelled to drive the car with dragging brakes, or anything of that kind.

Tires

Considerable progress has been made in the quality of tires. I believe most of the best-known tires today, especially those of the cord type, give about uniformly good results. There is such a thing as over-tiring as well as under-tiring a car. Tires of adequate size only should be installed; I do not believe in what might be called the over-sizing of tires. I am assuming, of course, that the tire is properly selected in the first instance.

In the matter of oil economy, I think it is possible to obtain too much oil economy at the expense of something else. When we did not have the oil under control, we were constantly trying to reduce the oil consumption. I have been astonished to find out how little oil I could use but, after more experience, I learned that this reduced oil consumption was not all that I had thought it would be. With less lubrication, particularly with decreased cylinder lubrication, I found that I got into many other difficulties such as increased condensation in the crankcase, general wearing out of piston-rings and the like. So long as we use the present fuel we will have trouble with condensation in the crankcase and with the oil. Therefore, the oil should be changed occasionally. The best way to insure that the oil will be changed is to use a reasonable amount of it, although not enough to cause trouble.

Tire economy is an important item of saving. We will get the best tire economy if we build chassis with good brakes, smooth engines and gearboxes, so that we will get a smooth pick-up. An all-around smoothly operating car will give the best car economy per ton-mile. We cannot lay down rules as to how large or how small we will build cars, because different kinds of people demand different kinds of service.

Service Requirements

Another item that is apt to be overlooked in some cases is the matter of design from the viewpoint of service. The principal items, aside from the first cost of the car, are probably tire repair and depreciation. Tires, next gasoline and lastly oil are the main supply items. Service will cost in proportion to how simple, sensible and reliable the design is. We should pay more attention to simplicity. We think we have been paying attention to reliability and, after that, simplicity and accessibility. All cars have been offenders to some extent in lack of accessibility. It is good experience to operate some of the newly designed cars and to maintain them oneself for a few months before talking about turning them over to the factory; in that way one finds out what parts must be taken off to gain access to some other part that requires attention.

As to the matter of performance, I am inclined to agree that people do not like to shift gears, because they are

hard to shift. We must recognize the fact that greater gasoline economy requires more gearshifting. We have been making the gearshift harder because, as the parts speed up per mile traveled, the parts that must be handled in shifting gears increase in effective weight rapidly. Still, there has been much improvement along the line of

gearshifting. Whether the gearbox should have consideration I am not prepared to say. Certainly it should if we make any great changes in the matter of performance. In other words, in the interest of economy we may approach nearer to the European type of car and if so we must improve the gearshift.

ENGINEERING AS A PROFESSION

(*Concluded from page 496*)

stantly in mind the necessity of production and studies the methods of production almost as carefully as the general functioning of the design and the production department conscientiously endeavors to carry out the ideas of the engineer as closely as possible in actual production that there can be any real approach to the efficiency of the old one-man system in which the design and production were controlled by the same directing head. It is equally necessary that for a design to be commercially successful it be attractive to the public, both in its operation and in the price at which it can be sold at a profit. This is where the opinion of the engineer ought to be of great value on questions that are often decided by the sales division. The engineer with a proper training and a correct point of view should be the best judge of what can be produced to meet most nearly the public demand in any particular field.

LEADERSHIP IN THE CONSERVATION MOVEMENT

This very brief study of what engineering has done, what it frequently is and what it can be, has been introduced to make clear the tremendous opportunities that in my opinion will be open in the future to the men having a thoroughly sound engineering training. There is another phase of this question that deserves consideration. In the industrial history of this rapidly growing country there is every evidence that the great pressure of haste has caused the doing of many things in inefficient and uneconomical ways. Whether or not the wasteful methods of the past have been always justifiable, there can be no question that the time has come when everything possible must be done to conserve what remains of our originally tremendous natural resources. It is

only necessary to mention timber, coal and petroleum to emphasize this point. The trained engineer is better qualified than anyone else to take the lead in this important work.

What has been said previously regarding the great future for the profession of engineering shows also the value of a proper engineering education. Such an education is not only of value to those expecting to engage in engineering occupations but also to those intending to take part in general productive or operating activities. The underlying idea in the best engineering schools is to teach the habit of concentration and to encourage clear and logical thinking, the actual knowledge gained during the years of study being considered a valuable incidental but not the main object of the work. It is hardly believable that this mental training will not prove to be a fine preparation for many of the difficult tasks that are daily to be met with in the industrial world of today, whether these tasks are of an engineering nature or more directly concerned with problems of direction or of management.

It is recorded of President Lincoln that after he had grown to manhood he made a most thorough study of Euclid because he believed that this would help him in formulating his ideas and in presenting them clearly to others. His conclusion was that the most complicated proposition could be put in such simple form as to be demonstrated to and understood by the least intelligent. What more convincing argument could there be as to the general value of this kind of training than that it was made use of by our great president in developing a truly remarkable ability for meeting the many difficult situations arising during his presidency and promptly reducing to the simplest terms the problems presented to him?

THE BASIC INDUSTRY

(*Concluded from page 506*)

and a more interesting school. In this school, agriculture, domestic science and manual training are taught.

A study of all the farm homes in Orange Township, Blackhawk County, Iowa, was made by the Iowa State College. Half of all the farm homes in this township had furnaces, while the proportion having water, baths and electric or gas lights was somewhat less. Nearly half of the homes had such labor-saving conveniences as vacuum cleaners, power washing machines and electric irons. Nearly all these homes had telephones, more than half had pianos and about half of them had automobiles. Each home improvement calls for others. For example, it is the general experience of distributors of electric lighting-plants that the purchase of a lighting-plant is followed by the purchase of a considerable amount of better furniture and house furnishings. Better wall paper is required. More paint and varnish are used. When the electric lights are turned on, the rugs, the furni-

ture and the other house furnishings, which seemed satisfactory when kerosene lamps were in use, are not now so attractive.

The electric powerplant makes it far easier to have a water system in the farm house, with indoor toilet and bath, and to have the water system 100 per cent efficient. The power washing machine, the electrically operated ironing-machine, the vacuum cleaner, the electric iron and the electric fan can be utilized. The water can be pumped, the churn operated, the grindstone turned, the cream separated and a variety of other minor operations performed in and about the farm home by electric power.

The forces of necessity and desire are working together to increase the complexity of relationships between the farming element and the rest of the country, and interdependence beyond the mere traffic in food is generally recognized.—Guaranty Trust Co. of New York.

Publications of Interest
to
S. A. E. Members

In this column are given brief items regarding technical books and publications on automotive subjects. As a general rule, no attempt is made to give an exhaustive review of the books, the purpose of this section of THE JOURNAL being rather to indicate from time to time what literature relating to the automotive industry has been published with a short statement of the contents.

ANGLES OF ATTACK AND AIR SPEEDS DURING MANEUVERS. By Edward P. Warner and F. H. Norton. National Advisory Committee for Aeronautics Report No. 105. Published by National Advisory Committee for Aeronautics, Washington. 12 pages.

In seeking further information as to the nature of maneuvers and as to the maneuverability characteristics of airplanes, continuous measurements of the angles of attack and air speeds at several points along the wings were made during spins and loops. Very striking results were obtained with reference to the rolling velocity and the distribution of load in spins and the variation of the angle of attack in loops, a surprisingly large range of angle being experienced during slow loops.

PHYSICAL PROPERTIES OF MATERIALS. Bureau of Standards Circular No. 101. Published by Superintendent of Documents, Government Printing Office, Washington. 52 pages.

This circular aims to present in readily accessible form the best available data on the strength and related properties of materials. Among those treated are iron, carbon and alloy steels, wire and wire rope, semi-steel, aluminum, copper, miscellaneous metals and other alloys, rope, rubber, leather and wood. The tensile strength, proportional limit, percentage of elongation in 2 in., percentage reduction of area, Brinell and scleroscope hardness corresponding to a certain composition, density and method of preparation are shown in most cases for the metals and alloys. The S. A. E. Standard steels are covered fully in these tables. In addition, figures are given in many instances for the compressive and shearing strengths, moduli of rupture and Erichsen values. The circular also includes definitions of the properties treated and references to sources.

REPORT ON PERFORMANCE AND DESIGN OF FIVE REPRESENTATIVE GEARED AVIATION ENGINES. Air Service Information Circular, Vol. 11 No. 143. Published by the Chief of Air Service, Washington. 34 pages.

This report embodies complete descriptions of American-built geared engines with data on performance tests. The tests conducted were not sufficiently comprehensive to warrant definite conclusions as to the relative merits of the various types. The results indicate, however, that while several apparently successful forms of gearing are available, the engines themselves must be better adapted to the increased stresses due both to the presence of the gear train and to the high speed at which geared engines are usually operated. Data giving the mean effective pressure, fuel consumption, torque, horsepower, mechanical efficiency, etc., are tabulated for each test.

EDUCATION FOR HIGHWAY ENGINEERING AND HIGHWAY TRANSPORT. Department of the Interior, Bureau of Education, Bulletin No. 42, 1920. Published by Government Printing Office, Washington. 134 pages.

On May 14 and 15, 1919, a conference on education for highway engineering and highway transport was held at Washington which was attended by about 75 highway engineers, deans and supervisors of engineering in colleges, universities and technical schools, National, State and county highway commissioners, and men interested in highway and automotive transportation. The proceedings of the conference have been edited for publication as a bulletin of the Bureau of Education which contains much material of immediate and practical value to those who are directly interested in the problems of education for highway engineering and highway transport.

THE FACTORS THAT DETERMINE THE MINIMUM SPEED OF AN AIRPLANE. By F. H. Norton. National Advisory Committee for Aeronautics Technical Note No. 54. Published by the National Advisory Committee for Aeronautics, Washington. 9 pages.

A large range between the maximum and minimum speeds of an airplane is of undisputed value, either to permit safe landings in small fields with the medium or slow-speed machine, or to permit landing at all with very high-speed machines. The factors which limit the maximum speed are well understood, but rather strangely the limiting factors of the minimum speed have seldom been understood. The factors that affect the minimum speed are discussed with the hope that some of the present uncertainty will be cleared up.

THE FREEZING POINTS AND SPECIFIC GRAVITY OF ALCOHOL-WATER MIXTURES. Air Service Information Circular, Vol. 11 No. 178. Published by the Chief of Air Service, Washington. 6 pages.

Solutions of alcohol and water were prepared having a concentration at 2½-per cent intervals from 0 to 50-per cent concentration of alcohol by volume. These solutions submitted to low temperatures causing complete solidification or freezing of the mixtures, the melting point being determined upon slow warming. Tables show freezing point and specific gravity of denatured alcohol-water mixtures at 2½-per cent intervals from 0 to 50 per cent by volume of alcohol, these data also being reproduced in graphic form.

THE CALCULATED PERFORMANCE OF AIRPLANES EQUIPPED WITH SUPERCHARGING ENGINES. By E. C. Kemble. National Advisory Committee for Aeronautics Report No. 101. Published by the National Advisory Committee for Aeronautics, Washington. 52 pages.

In this report are presented the theoretical performance curves of an airplane engine equipped with a supercharging compressor and a graphical method is outlined whereby performance curves for either type of engine-compressor unit at all speeds and altitudes may be laid out with the aid of assumed compressor characteristics. Comparative performance curves for a Liberty engine operating with a turbine-driven compressor, a gear-driven compressor and without supercharging are derived in an illustrative calculation. A supercharging installation suitable for commercial use is described, and it is shown that with the aid of the compressor a great saving in fuel and a considerable increase in carrying capacity can be effected simultaneously.

RECENT EUROPEAN DEVELOPMENTS IN HELICOPTERS. National Advisory Committee for Aeronautics Technical Note No. 47. Published by National Advisory Committee for Aeronautics, Washington. 18 pages.

This report, which was prepared by the Paris Office of the National Advisory Committee for Aeronautics, describes two experimental types of helicopters developed during the war. One is designed to serve as a captive machine for artillery observation. A model of this type propelled by three rotary engines driving dual propellers actually ascended to a height of 50 meters. It possessed an excess lift equivalent to the weight of four men on the ground. A photograph is shown of this machine in flight.

APRIL COUNCIL MEETING

THE April Council meeting was held in Detroit on the 25th. The Council received a report from the Research Committee which held a meeting in Detroit on the same day.

ACTIVITIES OF THE SECTIONS

THE Annual Nominating Committee of the Society will meet during the Summer Meeting at West Baden and perhaps make its selection of candidates for officers of the Society for the year 1922. Each Section elects one member to serve on this Committee and it is desirable that the delegates so chosen have adequate knowledge of the wishes of the members of their Sections as to the men to be proposed for the various offices in the Society. Suggestions along these lines given to the delegates will be carefully considered by the Committee.

The number of reservations for the Summer Meeting received at the middle of April is shown below, geographically distributed as indicated.

Connecticut	7
Illinois	29
Indiana	39
Iowa	1
Massachusetts	6
Michigan	118
New Jersey	11
New York	75
Ohio	90
Pennsylvania	35
Virginia	1
Wisconsin	3
	——
	415

A special train will run from the East over the Pennsylvania system to West Baden. The train schedule will be

Monday, May 23

Leave New York (Pennsylvania Station)	9:10 a.m.
Leave North Philadelphia	11:16 a.m.
Leave Washington	10:10 a.m.
Leave Baltimore	11:15 a.m.
Leave Harrisburg	2:00 p.m.
Leave Altoona	5:00 p.m.
Leave Pittsburgh	8:25 p.m.

Tuesday, May 24

Leave Columbus	12:35 a.m.
Arrive West Baden	11:00 a.m.

Special cars will also leave from Chicago, Cleveland, Detroit and Indianapolis. Members in these districts should communicate regarding train accommodations with the Secretaries of their respective Sections whose names and addresses are given below.

Cleveland Section—A. E. Jackman, Secretary
1900 Euclid Avenue, Cleveland
Detroit Section —M. H. Cox, Secretary
1361 Book Building, Detroit
Indiana Section —B. F. Kelly, Secretary
Weidely Motors Co., Indianapolis
Mid-West Section —L. S. Sheldrick, Secretary
910 South Michigan Avenue, Chicago

Round trip transportation at a fare and one-half has been arranged from all points east of Chicago and St. Louis, north of the Ohio River, and of Washington and Norfolk, except New England. Members from New England may secure the reduction from New York or Albany. These special rate tickets must be used within certain time limits and over the same route in both directions and are not good for stopover except between connecting trains. Reservations may be made on the S. A. E. special train or Section cars by those purchasing either one-way or round-trip tickets.

RECENT MEETINGS

At one of the best attended meetings of the season, held at the Cosmos Club on April 1, Brigadier-General William Mitchell told the members of the Washington Section of the plans being made to test during the coming summer the effectiveness of aircraft attacks on battleships. In his description he stated that no defense from the ground or water would be efficient against an attack from the air and that only counter-attack from the air could be depended upon. Anti-aircraft fire was used during the war chiefly to protect balloons.

Six thousand feet was given as the best altitude for bombing from the air and present accuracy was stated to be about 10 times better than it was in the past war. Three-inch deck armor is the limit of thickness that can be pierced by gravity bombs but it is not known yet whether it is necessary to actually pierce this armor as the bombs may do sufficient damage otherwise. This is one of the questions it is planned to settle in the bombing tests this summer. England and France, General Mitchell said, are now carrying out similar tests. A striking comparison was made between the total weight of three types of missiles and the weight of the explosives they carry. Shells contain only 2½ per cent of explosives, and torpedoes 20 per cent, while aircraft bombs have over 50 per cent of their weight in explosives. The Air Service is planning to attack ships first with gas bombs, then with 300-lb. high-explosive bombs, following with 1100-lb. high-explosive bombs. The 1100-lb. bombs are expected to have a serious effect on a ship if they drop within 60 ft. of it. It is planned to make tests of this on one of the surrendered German battleships. The General described some recent American developments in airplanes and bombs, stating that the United States is making very rapid advances and that all-American equipment of excellent performance ability has been developed, making this country independent of foreign sources. In concluding he said in reply to a question that the battleship is not yet obsolete but that it might be superseded by aircraft within the next 20 or 30 years.

Major H. W. Harms, technical expert of the Air Service, gave a comprehensive account of the aircraft and equipment being developed by the Air Service, illustrating his talk with numerous lantern slides. The Air Service plans to develop four general types of airplane for 15 kinds of service, an effort being made to combine the various requirements in a small number of machines with the object of standardizing them.

Officers of the Washington Section for the coming Section administrative year were elected. Dr. H. C. Dickinson and Wm. S. James were named member and alternate to represent the Washington Section on the Annual Nominating Committee of the Society which will be organized at the Summer Meeting at West Baden.

Repair Equipment, by B. M. Ikert, and Welding, by Lorn Campbell, Jr., were the subjects presented before the Minneapolis Section at its meeting on April 6.

H. M. Beck gave a paper at the meeting of the Mid-West Section on April 11. His subject was Automatic Charging of Motive Power Batteries.

R. H. Beach and A. J. Weiss described a carburetion system which was developed for using kerosene and other fuels of low volatility in internal-combustion engines at the meeting of the Metropolitan Section held on April 14. The operation of the system is based on the heating of all of the mixture at low speeds in a coil which is enclosed in an exhaust chamber; at high speeds, the throttle is arranged so as to pass the charge directly into the cylinder. A lively discussion was had and some of the difficulties of utilizing kerosene as a fuel in passenger-car engines were brought out. It seemed to be the general opinion that the field for kerosene is limited to tractor, marine and stationary engines, where full-load conditions prevail most of the time.

That the sentiment of motor-car builders is turning more and more toward the possibility of lighter-weight construction is evidenced by the increasing number of discussions being held on this subject, one of which was led by Laurence Pomeroy at the Cleveland Section meeting on April 15, the subject being Aluminum in Engine Construction.

Another talk dealing with the subject of lighter weight was given by John D. Cutter before the Detroit Section on April 22. Mr. Cutter's paper was on Molybdenum Steel. When it is noted that about three-quarters of the weight of a car is

of steel, it will be recognized that the use of steel alloys has an important bearing on the total weight of the car.

The paper presented by A. E. White before the Detroit Section meeting on March 25 was received with unusual interest and, because of sentiment voiced at the meeting, it will be found elsewhere in this issue of THE JOURNAL.

F. C. Mock spoke on Carbureter Performance at the Buffalo Section meeting of April 19.

The Pennsylvania Section elected its officers for the coming year at its meeting on April 20.

Operating characteristics of Lead Acid Batteries was the subject of a paper read by H. W. Beedle at the Boston Section meeting on April 22.

During the past year the membership of the Society in California has increased from 116 to 154. This growth has been due largely to the efforts of the local Membership Committee. This committee has recently held a series of luncheons in San Francisco at the last of which on March 22 a group of over 30 members and guests listened to an informal talk by Past-President H. W. Alden of the Society. Col. Alden sketched the work and history of the Society, and referred to the possibility of forming a Pacific Coast Section. He spoke also of the recognition which automotive engineers must give to the problem of good roads and of the necessity of working with the highway engineers for the betterment of roads so necessary for the successful operation of the motor car and truck.

COMING MEETINGS

Section meetings scheduled for the month of May include one of the Indiana Section at Indianapolis on the 5th and a meeting of the Washington Section the following night. The Mid-West Section will hold a dinner and smoker on the 13th. It is expected that the final meeting of the Dayton Section for the present season will be held on the 17th and that of the Cleveland Section on the 20th.

THE TRACTOR ON CORN-BELT FARMS

WHILE the saving of man labor is frequently mentioned as an important advantage of the tractor, this factor does not seem to be of great importance in the corn-belt section. Some man labor is saved when a tractor is used in pulling a three-bottom plow instead of the two-bottom plow commonly used with horses. Some saving in man labor is effected also when discing and harrowing are combined as one operation. The combining of other operations such as harrowing and rolling may make possible some saving in man labor. However, the total saving in man labor effected by the tractor in performing the various operations of soil preparation does not appear to be more than a few days, from 10 to 15 perhaps on the average-sized farm using a tractor. This saving is not of very great importance because it is made during a period when horsepower rather than man labor is the limiting factor in getting the work done. The peak-load requirement for man labor does not come at the time of spring planting. It comes later on in June and July, at the time of corn cultivation, wheat harvesting and haymaking. At this season the tractor can effect little if any saving in man labor.

The data available from the Illinois tractor farms studied up to the present time indicate that as an average the tractor has displaced slightly more than 20 per cent of the horses carried before adding the tractor. Under the most favorable conditions and with the best management the maximum displacement has been almost exactly 33 per cent.

As an average of the first 100 tractor farms studied in six central Illinois counties it was found that the average size was 294 acres and that these farms grew slightly more than 240 acres of crop. On the average these farms used slightly less than 12 horses per farm, that is, they worked a little more than 20 acres of crop per horse. The tractor used displaced slightly less than 2½ horses per farm.

As a result of the studies made so far, based on the experience gained by Illinois farmers in 1918, 1919 and 1920, it appears that farms with less than 200 to 240 acres of crop have not been justified in using a tractor. Under special conditions where the demand for belt work is unusual or the tractor possesses special advantages because of the conditions obtaining on a particular farm, a tractor may prove to be a profitable investment even though the farm be considerably below the size which is apparently best adapted to using a tractor.

It is, of course, plain that these general conclusions must be regarded as somewhat preliminary, and that they will, of necessity, be revised as additional experience is accumulated, and as investigations in this field are extended and the methods of study improved.—W. F. Handschin in *Orange Judd Farmer*.

NATIONAL SCREW THREAD STANDARDS

THE progress report of the National Screw Thread Commission, as approved June 19, 1920, has been published by the Government Printing Office as miscellaneous publication No. 42 of the Bureau of Standards. Copies may be obtained upon application to Superintendent of Documents, Government Printing Office, Washington. An extensive abstract of the report was published in the October, 1920, issue of THE JOURNAL, page 317, this being based on a tentative report issued prior to that time in mimeographed form. Recognizing the impossibility of making a report of this character which in its first edition is entirely free from error or inconsistency, the Congress has extended the life of the National Screw Thread Commission for a period of 2 years, during which time such corrections and changes will be made in the report as are found necessary or desirable by practical trial of the recommendations of the Commission in the designing room and the shop.

The National Fine-Thread Series which conforms to the S. A. E. Standard regular thread is recommended for general use in automotive and aircraft work when the design requires both strength and reduction in weight and special conditions require a fine thread.

The general adoption of the S. A. E. Standard pitches in other than automotive lines of work is indicated by the practice of a well-known automotive company.

In this plant where pitches finer than U. S. Standard have in the past been used they are replaced at the first opportunity with S. A. E. Standard pitches. In new designs, where holes are tapped in steel, the S. A. E. Standard pitches are used.

Instead of tapping cast iron for binder bolts, through-holes are drilled wherever possible and S. A. E. Standard bolts used. The past practice of tapping holes in cast iron, brass and other soft metals, for U. S. Standard pitches, is continued except in a few instances where S. A. E. Standard pitches are being tried because the workmanship is more refined.

In the few instances where S. A. E. Standard pitches have been used, both in cast iron and in bronze, no trouble has so far resulted. The successful application of S. A. E. Standard pitches in such cases, however, is contingent largely on careful workmanship in tapping the hole and in the use of screws having threads that are smooth, full and accurately concentric. The use of S. A. E. Standard regular and fine pitches is being extended, insofar as they are adapted to the purpose, to the threading of component parts other than screws and bolts.

CURRENT STANDARDIZATION WORK

THE current standardization work of the Society has, in consequence of the general industrial situation, been carried on recently more extensively than usual by correspondence. Many Divisions are therefore holding but one meeting before the Semi-Annual Meeting of the Society on May 24.

The complete reports of the Divisions making recommendations will however be published in pamphlet form and sent to the voting members of the Society for consideration prior to the Standards Committee Meeting.

CHAIN DIVISION

A meeting of the Chain Division was held on Nov. 17, 1920, in New York with the Roller Chain Committee of the American Society of Mechanical Engineers and the Committee on Sprockets of the American Gear Manufacturers Association. The session was given over largely to discussion of a standard tooth-form, the following recommendation being submitted for consideration:

> The pressure angle for a six-tooth wheel shall run from about 15 to 5 deg. The pressure angle on a wheel of infinite diameter shall run from about 15 to 30 deg., making the actual working face of the tooth a surface concave to the roller, the radius of which is approximately 1.3 times the diameter of the roller

This recommendation was adopted with the understanding that the Subcommittee on Tooth-Form would present a detailed report at a later date which would be considered approved unless some objection was raised by the Division members. The complete report is now before the members of the Division for letter ballot.

The Division recommended also the adoption of a numbering system for roller chains in which the left-hand figures denote the number of one-eighth inches in the pitch and the final figure denotes the roller diameter, "O" indicating that the roller diameter is for the heavy series, "1" indicating that it is the same as for chains of the medium series, and "2" indicating that it is the same as for chains of the light series, the numbers being followed by the letter "W" or "N" denoting whether the chain is of the wide or narrow series. Thus in a chain number 4OW, the 4 shows that the pitch is ½ in.; O that it belongs to the heavy series and has a 5/16-in. roller diameter; and the letter W that it belongs to the wide series and that its width is 5/16 in.

Further work on the subjects of rollerless bushing chains and average breaking strengths is planned.

ENGINE DIVISION

A meeting of the Engine Division was held on April 18 at Cleveland in the Old Colony Club rooms, the subjects of mufflers, carbureter flanges, engine testing-forms and fan belts and hubs being discussed.

ISOLATED ELECTRIC LIGHTING PLANT DIVISION

The Isolated Electric Lighting Plant Division members met at Chicago on April 11. Ratings of storage batteries for isolated electric lighting plants was the principal subject discussed.

LIGHTING DIVISION

A Lighting Division meeting was held on April 15 at Detroit to consider Subdivision reports on universal fender-type head-lamp mountings, lamp nomenclature and bases, sockets and connectors.

The proposed type of head-lamp bracket for mounting on fender aprons has been tried out satisfactorily in actual practice. The bracket will permit of universal adjustment of the lamp and interchangeability of lamps. The recommendation presented at the meeting was

> The bracket shall have a spherical mounting surface providing universal adjustment of the head-lamp

The radius of curvature of the spherical mounting surface shall be 2½ in.

The axis of the bolt holding the head-lamp to the bracket shall coincide with the axis of the mounting surface. The bolt shall be ½ in. in diameter, 1½ in. long and threaded with ½-in.—20 S.A.E. thread for a distance of ⅞ in. from the end

The angle formed by the axis of the spherical mounting surface and the axis of the head-lamp shall be 55 deg.

A plane passed through the center of the spherical mounting surface perpendicular to the axis of the head-lamp shall show the center of the mounting surface to be 60 deg. from the vertical

The axis of the spherical mounting surface shall be perpendicular to the axis of head-lamps cylindrical in shape and 60 deg. from the vertical.

The spherical mounting surface shall be attached to the outside of the lamp body

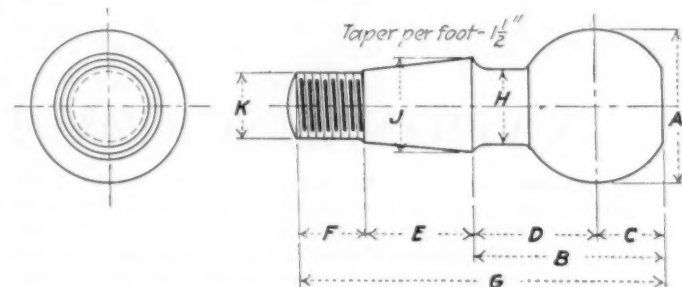No tie-rod lugs shall be made integrally with the lamp body

The bolt-holes in the fender mounting surface shall be 13/32 in. in diameter and the center-to-center distance shall be 3 in.

The fender mounting surface shall be parallel to the axis of the lamp

It is understood that the mounting surface of the bracket is the male part and the mounting surface of the head-lamp the female part.

PARTS AND FITTINGS DIVISION

A meeting of the Parts and Fittings Division was held April 19 in New York City. One of the principal subjects discussed was a report on ball studs ranging in size from 1 to 1¾ in. ball diameters which was presented by W. R. Strickland. Preliminary investigation showed that the variation of present practice made this fitting unnecessarily costly to the manufacturers and it was therefore requested that a standard should be formulated. The report which is in the form of a proposed standard is given in the accompanying table.

No.	A	B	C	D	E	F	G	H	J	K
1	1	1⅜	7/16	11/16	11/16	⅝	2 11/16	⅝	0.766	⅝-18
2	1⅛	1½	½	1	13/16	⅝	2 15/16	⅝	0.766	⅝-18
3	1¼	1 11/16	9/16	1⅛	1	¾	3 1/16	¾	0.875	⅝-18
4	1½	1⅞	⅝	1¼	1⅛	¾	3¾	13/16	1.000	¾-16
5	1¾	2⅛	¾	1⅜	1¼	1	4⅜	13/16	1.250	⅞-14

A Subdivision consisting of A. K. Brumbaugh, chairman, J. T. Spicer, H. G. Farwell, E. O. Christiansen, F. C. Stanley and Clarence Carson has been appointed to consider the subject of brake-lining dimensions and tests based on the work of the Truck Division Subdivision on Brake-Lining Specifi-

cations and Coefficient of Friction. This Subdivision did considerable work during 1920. A meeting of the Subdivision was held on April 1 in New York at which the subject of brake-lining tests was very thoroughly discussed, the work at the Bureau of Standards being described in detail. It was decided at this meeting that the members of the Brake-Lining Subdivision should construct testing apparatus similar to that constructed at the Bureau of Standards and make a series of tests with a view to deciding upon a definite specification for testing brake-linings. The importance of such tests was emphasized as the tests employed at the present time by the different automobile builders vary greatly.

Other subjects considered at the meeting were exhaust-pipe diameters, warning-signal mountings, serrated-shaft fittings, universal-joint companion flanges and lock washers.

PASSENGER CAR BODY DIVISION

The Passenger Car Body Division meeting held on March 11 resulted in the assignment to Subdivisions of many subjects germane to passenger-car bodies which are considered by the Division members to warrant the immediate consideration of the Division. Among the subjects assigned are:

Top Irons	Wood-Screw Drill Sizes
Fender Irons	Door Fit Clearances
Plate Glass	Sheet Metal
Window Runways	Beads for Wiring
Door Handles	Nickel Plating
Door Hinges	Tee Moldings

It was the consensus of opinion that it is quite possible that there are other subjects more important than the ones listed above which should be considered by the Division for the purpose of formulating standards which, through general adoption by the industry, would decrease the manufacturing cost of the parts standardized, increase the sources from which they can be obtained and tend to decrease the cost of the finished products. The Division members will therefore appreciate further suggestions in this connection.

ELECTRIC EQUIPMENT DIVISION

W. S. Haggott, chairman of the Subdivision on Insulated Cable, submitted a report at the meeting of the Electrical Equipment Division held on April 19 in Cleveland. This report was formulated after a series of Subdivision meetings attended by cable and electrical equipment manufacturers. The tests outlined in the report were based on the results of tests which have been carried on by members of the Subdivision. The complete report will be published in the pamphlet containing the reports of the Divisions of the Standards Committee, which will be sent to the members before the Standards Committee meeting on May 24.

Other subjects considered at the meeting were ignition distributor mountings, flexible-disc couplings and magneto, generator and starting-motor mountings.

STATIONARY ENGINE DIVISION

A meeting of Stationary Engine Division members was held on April 13 at Waterloo, Iowa. Returns from general letters which had been sent out by the Society on the Division's recommendation on Stationary Engine Belt Speeds and Spark-Plug Hoods and Pulley Lug dimensions, which had been suggested for standardization, were considered. Several Subdivisions also presented progress reports.

VALVE-STEEL SPECIFICATIONS

AT the Standards Committee Meeting held last January certain S. A. E. Steels were unjustly criticized to the effect that nickel and nickel-chromium steels which were recommended for use in engine valves scaled excessively at high temperatures. It is generally understood that the Iron and Steel Division has not recommended specific compositions for valve purposes for many years and never recommended any of the nickel-chromium steels. Confusion has, however, been caused by the fact that in the notes and instructions typical applications have been listed indicating the use made of certain compositions covered by the S. A. E. Steel Specifications. These notes are published as general information only, not as an S. A. E. Standard or Recommended Practice. It is clearly stated, and is in general understood throughout the industry, that the notes and instructions are added solely for information of the users of the steel and do not constitute a part of the iron and steel specifications.

The main reason for not making specific recommendations a part of the S. A. E. Standards is that very frequently a wide range of material is used successfully for the same automotive part, and the selection of a specific material for a given use depends upon the design, production methods and many other factors that must be given careful consideration by the metallurgist or engineer in direct charge rather than by a metallurgical body working at a distance. The notes covering the tungsten steel specifications state that Specifications Nos. 71360 and 71660 are suitable for high-tungsten steel exhaust valves and that Specification No. 7260 is suitable for low-tungsten steel inlet and exhaust valves. "General Information" on high-chromium steel containing from 11 to 14 per cent of chromium is also published in the S. A. E. HANDBOOK and states that one of its principal uses is for exhaust valves in airplane engines. No other mention of valve steels is made.

A survey of what steels were used in actual practice for inlet and exhaust valves was made by the Society in 1920. A tabulation of the results is given in the accompanying table, the figures indicating the percentage of engine builders and valve manufacturers using each material for inlet or outlet valves. These data were based on returns received from 38 representative engine builders and valve manufacturers.

RELATIVE USE OF ALLOY STEELS FOR VALVES IN PERCENTAGE

Material	Inlet Valves	Exhaust Valves
Cast Iron	31	26
Nickel Steel	18	14
Chromium-Vanadium Steel	6	3
Nickel-Chromium Steel	19	18
High-Tungsten Steel	6	10
Low-Tungsten Steel	11	12
Carbon Steel	2	3
High-Chromium Steel	7	14

THE EDUCATIONAL SYSTEM OF THE ARMY

WITH a view to meeting the numerous requests for information concerning the educational and vocational training program of the Army and to set forth in a convenient form the plans and desires of the War Department for the improvement and recreation of the young men enlisting, a pamphlet has been prepared for distribution. Those who are interested in this important work can secure copies by addressing the Adjutant General's Office at Washington and asking for the pamphlet entitled The Educational System of the United States Army.

Applicants *for* Membership

The applications for membership received between March 26 and April 19, 1921, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ALEXANDER, C. K., sales engineer, Wheeler-Schebler Carburetor Co., *Indianapolis.*

ALVORD, C. H., factory manager, Gray & Davis, Inc., *Cambridge, Mass.*

ANDREW, DAVID, JR., secretary and sales manager, Arco Co., *Cleveland.*

BLUM, LOUIS E., JR., machine designer, Splitdorf Electrical Co., *Newark, N. J.*

BOYD, FRANK MORRISON, general manager, secretary and treasurer, Motor Parts Corporation, *Baltimore, Md.*

BRADY, L. J., assistant manager, Nash Sales Co., *Chicago.*

BRICE, JAMES W., International Finn Recorder Co., *Endicott, N. Y.*

BROCKETT, ASHLEY H., instructor, Carnegie Institute of Technology, *Pittsburgh.*

BROWN, GORDON, research engineer, Condensite Co. of America, *Bloomfield, N. J.*

BULLOCK, HOWARD F., district representative, United Motors Service, Inc., *Detroit.*

BURTON, EWART E., mechanical draftsman, Holt Mfg. Co., *Stockton, Cal.*

BUTTNER, EDGAR LOUIS, student, University of California, *Berkeley, Cal.*

CAMINEZ, HAROLD, aeronautical designer, Air Service, McCook Field, *Dayton, Ohio.*

CAREY, LIEUT. EDWIN F., office of Chief of Air Service, *Washington.*

CARVELLI, GUSTAF, designing engineer, Curtis Engineering & Motors Corporation, *Garden City, N. Y.*

CIAFFONE, JAMES V., designer and inventor, 427 12th Avenue, *Long Island City, N. Y.*

CONANT, DAVID J., chief engineer, Western Well Works, Inc., *San Jose, Calif.*

DALE, HARRY W., mechanical and research engineer, 2626 Broadway, *New York City.*

DANFORTH, I. W., sales manager, Gabriel Mfg. Co., *Cleveland.*

DAVIES, W. S., auto engineer, Wolseley Motors Ltd., *Birmingham, England.*

DEBRAY, WILLARD S., machinist apprentice, Pennsylvania Railroad Co., *Altoona, Pa.*

DEMARINGH, ALBERT F., sales engineer, Marburg Bros., Inc., *New York City.*

DE WITT, L. W., sales agent, National Malleable Castings Co., *Cleveland.*

DISBROW, LIVINGSTON, experimental mechanic, Pittsburgh Model Engine Co., *Pittsburgh.*

ENOCHS, C. D., vice-president and general manager, Shaw-Enochs Tractor Co., *Minneapolis.*

EVELYN, STEVEN F., designing engineer, Continental Motor Corporation, *Detroit.*

FISHER, ROY R., president and general manager, Ray Battery Co., *Ypsilanti, Mich.*

GAFFNEY, MICHAEL W., body engineer, Haynes Automobile Co., *Kokomo, Ind.*

GALLAGHER, FRANK J., technical assistant to fire marshal, *Philadelphia.*

GANDELOT, HOWARD K., service manager, B. W. Lemmon Co., *Pittsburgh.*

GATES, L. S., head of Gates & Co., *New York City.*

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The following applicants have qualified for admission to the Society between March 10 and April 9, 1921. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

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